Practicing Historical Ecology

Methods for the Collection, Analysis, and Integration of Interdisciplinary Historical Data

Scott Madry
Anna Westin
Elizabeth Jones
(editors)

Published by the SLU Swedish Biodiversity Centre,
Swedish University of Agricultural Sciences

Editor: Scott Madry, Ph.D., Anna Westin, Ph.D., Elizabeth Jones, Ph.D
Publisher: Swedish University of Agricultural Sciences,
SLU Swedish Biodvdiversity Center
Year of publication: 2024
Title of series: CBM:s skriftserie nr 130
DOI: https://doi.org/10.54612/a.389ecand8n
ISBN: 978-91-88083-45-6
ISSN: 1403-6568
Cover pictures: Background map: Cadastral map from 1734, Andersby, in the county of Uppsala, Sweden. From left to right: Coppice forest close to Marisel village, Cluj county in Romania (photo Anna Westin). Postcard aerial photo of Uxeau village, Burgundy in France, taken around 1950. Mowing on ice on “Frosktjernet”, november 1920, Trysil Engerdal museum (photo Haakon Garaasen PDM). A digital GIS version of an 1834 cadastral map of the commune of Uxeau village, France. Herbarium sheet, by courtesy of Swedish Museum of Natural History. Page from the diary of Norra Strandmora, County of Dalarna in Sweden.

Copyright © 2024 Scott Madry, Anna Westin, Elizabeth Jones.
All rights reserved.

DEDICATION

This volume is dedicated to the many scholars, past, present, and future, who dedicate their efforts to advancing our ability to understand our place in the world.

CONTENTS

SECTION 1

INTRODUCTION

This section sets the stage for the individual chapters in this volume. We begin with the foreword by Prof. Carole Crumley, and the publisher's foreword by the former director of the Swedish Biodiversity Centre, Prof. Tuija Hilding-Rydevik. This is followed by our editor's introduction to our work and our acknowledgements. This first section ends with our first chapter, which presents a general introduction to Historical Ecology, what it is, where it comes from, and how, in general, it is conducted.

FOREWORD

CAROLE CRUMLEY

Since its appearance in the early 1990s, the research framework of historical ecology has garnered increasing interest with an influential role in the organization of many projects. The origins of the framework are twofold: one from the natural sciences (forestry, ecology) and the other from the social sciences (anthropology, archaeology).

For archaeologists and cultural ecologists, it is always necessary to engage the Earth systems disciplines, and for natural resource managers it is helpful to know how information about previous strategies could be useful for the future. Historical ecology's ethical stances are useful for everyone. It is, then, quite easy to come upon research from around the world that has utilized the themes and practices that anchor historical ecology, but it is much more difficult to encounter step-by-step instructions on how to proceed with your research. The place-based nature of historical ecology demands that every would-be researcher become familiar with the information which is, or might be, a necessity for building the historical ecology of a particular landscape.

This survey of categories of information is enormously important, albeit daunting for a lone researcher. For this and many other reasons, the presence in the research group of individuals from diverse knowledge communities is fundamental to historical ecology. These individuals can ensure that a first effort at comprehensive coverage begins well. Ultimately something will surely have been forgotten, or new tools or information will appear, and the group will be ready for that challenge. Planning a research project that is anchored in historical ecology is difficult, but ultimately rewarding. However, planning a handbook that encompasses all potential sources of information for every place in the world is impossible.

While the utility, basic techniques and findings of some research tools are widely known and reasonably well understood (archaeology, geology), many arenas that use contemporary statistical, mathematical, ecological or social science techniques are less likely to publish advice for the novice. The obvious solution is to find a team member who is skilled in that specialty, but this side-steps the need for the entire team to have some familiarity with the research tool in question. To do otherwise blocks the creative flow: the historian is unaware that early dam structures can be located in a heavily forested area with sharp new tools, and the LiDAR specialist does not think to ask the historian how she can help with the study of early water management systems.

This book offers practical aid in understanding some very important but, for many researchers, difficult tools to master. Organizing researchers (those who write proposals, plan the scope of work, engage colleagues to join the project) do not need to become professionally competent in every area that will be part of the research, but they do need to understand the fundamentals and thus see the potential for such tools in the proposed research. So do their research colleagues, as thus begins the collaboration.

The editors, many of whom are long-term colleagues, have put together an understandable and useful volume, intended to provide basic understanding of many key resources that make up historical ecology research. A very helpful addition to the literature, it can increase the scope and number of such projects in the future and around the world. I am delighted to recommend this book to you.

PUBLISHER'S FOREWORD

TUIJA HILDING-RYDEVIK

Our acknowledgement and the willingness to take concrete action for preserving the crucial role that biodiversity has for human wellbeing, economy and culture is very much needed. This book is important specifically for clearly presenting the scientific underpinning for understanding and addressing these relationships.

This volume is published by the SLU Swedish Biodiversity Centre (CBM), a research Centre with 27 years of experience in inter- and transdisciplinary studies in relation to biodiversity and its relationship to human action and thinking. The development of historical-ecology approaches and methods has been present since the start of CBM and is still ongoing.

Below, I make some remarks on the importance of this book from a learning-, CBM- and biodiversity perspective. These are important starting points perse and since theories of learning in relation to environmental sustainability implementation in public organisations is my research focus. And also, since I was the head of CBM 2011-2021.

Knowledge and emotions

Me, you, all people, nature and all matter on Earth are composed of the same small particles, quarks. All that lives on earth – me, you, all humans, plants and animals – are part of the circulation of water, nutrients etc., i.e. the cycle that drives the Earth's living system. All that lives are part of ecological systems that consists of organisms living in and interacting with the abiotic environment (air, rock, water etc.). In the face of life and death and the components of matter and its circulation, humans are at one with nature. Since the beginning of the evolution of humans, we have been, and still are, living in and from these ecosystems, and benefit from their biodiversity.

Why am I stating these obvious and self-evident facts? For me, stating these facts creates a strong feeling of belonging and togetherness. This also creates a strong motivation for my engagement with, and for protecting and sustainably using biodiversity. An insight that I would like to see more in our local and global policies, and in our daily professional and private lives. Bringing up feelings and motivation is related to theories of learning and change – as professionals and as private individuals. Since we live in an era asking for societal and social transformation in relation to the climate changes taking place and in relation to the deterioration of biodiversity, these theories are highly relevant. We also live in an era where the role of facts and science as a basis for policy and policy actions are themselves questioned, and we are having to deal with fact denialism.

Being motivated is an important driver for learning.[1] At the general level, learning can be described as "any process that in living organisms leads to permanent capacity change and which is not solely due to biological maturation or ageing" (Illeris, 2007, p. 7).[2] Illeris' definition (Illeris, 2007) includes not only change; the focus of interest is the change of capacity, i.e. the ability to do a particular thing, e.g. work with historical ecology. Furthermore, this changed capacity should be permanent, indicating change with a higher degree of consciousness and intentionality.

Learning in the workplace (such as a research department), which Illeris has been studying in particular (2004a), takes place in a dynamic relationship between employees' individual learning processes and the work environment. The work environment is comprised of the socio-cultural communities and the technical-organisational learning environment. Illeris (2004a, p. 432) illustrates this with a model in the form of a triangle, where human learning includes three key dimensions, which, in practice, are all part of every learning process (Illeris, 2009).

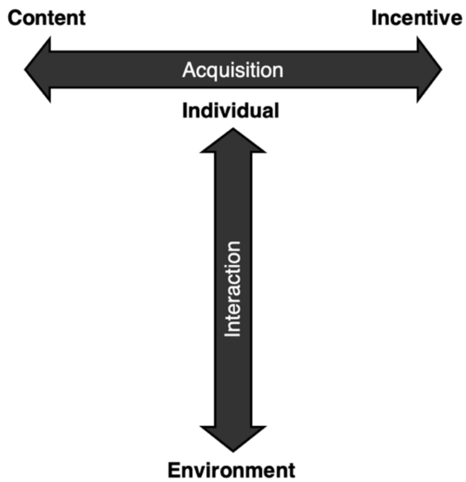


Figure 1. The triangle of human learning by Illeris (2009).

What is actually to be learned is the content dimension, comprising knowledge and skills (e.g. historical ecology methods) but also opinions, insight, outlook, attitudes, values and strategies. The second dimension is the incentive dimension, consisting of the learner's mental energy, feelings, motivation and volition. "The incentive dimension provides and directs the mental energy that is necessary for the learning process to take place" (Illeris, 2009, p. 10). These two dimensions are initiated by impulses from the third dimension, the interaction processes. The interaction dimension of learning contributes to integration in communities and society and thereby reinforces a learner socially. This is the dimension in which it is easiest to influence another person. It occurs in concrete interaction such as participation, communication and cooperation (Illeris, 2004b, p. 83), but also in situations in which an individual is (physically) alone, through her/his interplay with the environment as it is mediated through written sources (Illeris, 2004a, p. 434) (e.g this book).

Below I return briefly to the issue of learning in relation to the theme of this volume. First a few words about the SLU Swedish Biodiversity Centre (CBM) and transdisciplinarity.

The Convention on Biological Diversity

In December 2022, while writing this, the Fifteenth meeting of the Conference of Parties to the Convention on Biological Diversity (CBD) was ongoing in Montreal, Canada. CBD was one of the results from the UN Rio de Janeiro Conference, Earth Summit on environment and Development held in 1992. Since then, 196 countries have ratified the convention and now in 2022 representatives of all these countries are participating with the aim to reach an agreement on a post-2020 global biodiversity framework. At this meeting, the former head of CBM, Torbjörn Ebenhard, participated in the negotiations of this framework (on behalf of the EU and the chair country in 2022, the Czech Republic). Negotiations resulted in four overarching ambitious goals for biodiversity: its sustainable use, fair and equitable sharing of the benefits of genetic resources, and funding for the implementation. On top of that are 23 goals for 2030 targeting the direct driving forces for loss of biodiversity, how to approach the indirect driving forces and goals related to how to implement the overall framework. Target 21 concerns questions related directly to this book i.e. the need for "best available data, information and knowledge" and to strengthen "research and knowledge management". [3]

The SLU Swedish Biodiversity Centre (CBM), the publisher of this volume, has a special relationship to CBD. Implementing CBD in Sweden was the main reason for the Swedish parliament already in 1994, to give the Swedish University for Agricultural Sciences (SLU) and Uppsala university the joint task to initiate a National Centre for Biodiversity. And CBM was up and running in 1995. The origin of CBM was thus political, creating CBM to contribute to changes in the relation between society and biodiversity.

CBM and transdisciplinarity questioned

CBM flourished and grew from its start in 1995, and new, large research projects received funding from both academic sources as well as from the Swedish Ministry of Environment. The collaboration and communication with actors and organisations outside academia was integral to CBM's activities since the rationale for CBMs existence was to help Sweden implement the overall policy goals of CBD. In the 1990's, interdisciplinary or transdisciplinary research in relation to biodiversity was not that common, at least not in Sweden. But CBM created early on a transdisciplinary approach to its research and other activities. By transdisciplinary I mean interdisciplinarity combined with close collaboration with actors outside academia.

CBM has for a long period been perceived by academia as an anomaly, mainly for its transdisciplinary approaches. Its activities were questioned and put under scrutiny. In 2011, I was given the task from the Vice-Chancellors at SLU and Uppsala university to lead CBM through a process to enhance the role of humanities and social sciences. Coming from outside CBM, and then getting an overview of CBM activities, made it clear early on that the existing historical ecology research at CBM was one of three exciting and important areas that should be supported in the future. Additional funding was made available from the two universities to enhance the humanities and social science research in relation to biodiversity. As part of further developing historical ecology at CBM. Prof. Carole Crumley was appointed as a guest professor in 2012 with this funding. Anna Westin and Tommy Lennartsson and their collaboration with professor Crumley has been very important for the development of historical ecology at CBM. One important result from this funding and collaboration was an international workshop in 2015 arranged by Crumley, Westin and Lennartsson on methods and approaches in historical ecology. The discussions and new collaborations that arose from this workshop led to a fruitful process producing the volume Issues and concepts in historical ecology (Crumley; Lennartsson and Westin, 2017) engaging many international researchers and scholars. Westin and Lennartsson's historical-ecology knowledge has even been important inputs in more formal land use disputes in Sweden. The question in dispute was the biocultural value and traces of it, for a piece of land in question for resource exploration. The historical ecology approach at CBM is also used to understand how to support the biodiversity of roadsides by investigating the biocultural history of the road hinterlands.

All in all, understanding the needed conditions for preserving the biodiversity we have today is very much dependent on historical-ecological studies of the biocultural history of landscapes[4]. This is due to the fact that nearly all ecosystems have gained variation and diversity through traditional human use of these ecosystems. This is certainly the case for Europe, and most other parts of the world as well. The landscapes we have today, as a result of 100-150 years of industrialisation, are however biologically impoverished, abandoned or changed through overgrowth (or changed use). In order to restore and promote ecosystems and their biodiversity, we need to understand their history, and it often has to be quite detailed knowledge. This knowledge is however not yet a self-evident basis in biodiversity policies and conservation efforts. In our research at CBM, promoting this understanding is however an important starting point for different research projects and communication. More recently so in a research project focusing on governing pathways for promoting more multifunctionality in Swedish agricultural landscapes.

Methods, learning and transformation

At the beginning, I raised the crucial role of human emotions for creating motivation to learn. What creates emotions can be insights to something new, that you have not seen or understood before. New perspectives, combinations of perspectives and methods, areas you did not know anything about before. Something that reveals new ways forward for seeing and working with something in a new way – like in this volume. And we do very much need new ways forward. Today, transformative change is asked for in order to be able to conserve and sustainably use nature and its biodiversity. Transformative change implies "A fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values." (IPBES 2019, p. 14). And we need science and research supporting this change. Science that crosses academic boundaries and integrates multiple perspectives in order to create new and more multifaceted pictures of the complex interrelationships between humans and our environment. Also, history is always with us – culturally and ecologically – whether we recognize it or not. Increasing the knowledge of methods to uncover our human-environment history is thus fundamental to the transformative change of human land use that we require, especially so in relation to biodiversity.

References

Crumley, C., Lennartsson, T. and Westin, A., 2017. Issues and concepts in historical ecology. Cambridge University Press.

Illeris, K., 2004a. A model for learning in working life. J. Workplace Learn. 16, 431–441.

Illeris, K., 2004b. Transformative learning in the perspective of a comprehensive learning theory. J. Trans. Educ. 2, 79–89.

Illeris, K., 2009. A comprehensive understanding of human learning. In: Illeris, K. (Ed.), Contemporary Theories of Learning. Learning Theorists in Their Own Words. Routledge, New York, pp. 7–20.

IPBES (2019): Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany.

Lindholm, K-J and Ekblom, A., (2019) A framework for exploring and managing biocultural heritage. Anthropocene, Vol. 25, March 2019, 100195.

Notes

[1] Learning can thus take any direction. Learning is neither good nor bad, it is just learning.

[2] Biodiversity/biological diversity is here used in the Convention on Biodiversity sense: "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. https://www.cbd.int/convention/articles/?a=cbd-02

[3] The four goals and 23 targets are found at: https://www.cbd.int/article/cop15-final-text-kunming-montreal-gbf-221222

[4] Biocultural refer to "an understanding of cultural landscapes as the result of long-term biological and social relationships, shaping the biological and material features of the landscape and also memory, experience and knowledge" (Lindholm and Ekblom 2019)

EDITOR'S PREFACE

SCOTT MADRY, ANNA WESTIN, AND ELIZABETH JONES

Introduction by Scott Madry

This book is intended to be both a practical guide as well as a thoughtful consideration of the methods, techniques, and underlying concepts of Historical Ecology. Our interest in these subjects reaches back many decades, and we have, individually and collectively, conducted analysis and managed various projects relating to these intertwined topics. We have learned many lessons and have made our share of mistakes, and we wanted to produce a useful and practical work that can guide both students and practitioners in this challenging and complex emerging field.

While Historical Ecology is gaining broader interest around the world and across many disciplines, we have been surprised at how few publications there have been that focus on how to actually *do* this work, as opposed to theoretical articles or papers presenting the results of an individual project. Thus, our intention is to provide in one volume an overview of many of the methods, techniques, and data used in the collection, analysis, and integration of complex regional historical projects. This is no small undertaking, and none of us knows enough to do this alone. This book is, like Historical Ecology itself, a group effort, and we hope that this work will find use as both a textbook and a body of work worthy of interest by emerging and established scholars and practitioners alike.

Our goal is to provide an integrated view of these very disparate methods and techniques, based in very different scientific disciplines and academic traditions. Therefore, we present each subject in a fairly standardized manner, in the hope that they can be evaluated consistently by the reader. For each, we present the disciplinary underpinnings and perspectives that underlay it, the basics of the use of these data and techniques, and the methods of collection and analysis. We present examples of our own work, as well as other projects using similar data and analysis techniques. It is important to be realistic regarding the benefits and limitations of these data, and so we also present an honest assessment of what each data type does well and the inevitable limitations that are associated with them as well. Ultimately, the question must be: what can we learn from this type of data, and what are the limitations and potential errors that they bring us, and how can we integrate these disparate data into an integrated whole.

The book is divided into seven sections consisting of 19 individual chapters, each focusing on an individual approach, technique, or technology used in Historical Ecology research. We begin in Section 1 with our introductions, forewords, and an introduction into the theoretical foundations and approaches for Historical Ecology, in order to set the stage for what is to follow. Next, in Section 2, we look at several of the most commonly used sources of information for such research. We begin with a look at historical documents, focusing on several examples of different document types and from several locations and research projects. Following this fundamental focus on historical documents, we present chapters on biological cultural heritage and biocultural diversity, paleoecology, placenames and toponymy, and conclude the section with a chapter on historical cartography.

Section 3 presents two chapters on the basic methods used in Historic Ecology research. These include chapters on the topics of ecological ethnology and ethnobotany, and landscape archaeology. In Section 4 we look at communications and outreach with chapters on museum collections and their role in the preservation and presentation of material culture, and a chapter on Engaged Historical Ecology. Next, in Section 5, we present several of the emerging techniques and toolkits that are now used in Historical Ecology work. Chapters here include basic overviews of Geographic Information Systems (GIS), aerial photography and photogrammetry, satellite remote sensing and digital image processing, Satellite Positioning, Navigation and Timing (PNT) systems like the U.S. Global Positioning System (GPS), and the important and emerging technology of digital archiving of all of this varied and complex data. This section ends with a look at the future, and how emerging disruptive computer technologies are going to rapidly impact how we do our work in the very near future. Section 6 seeks to 'tie it all together' and consists of three chapters covering the vital questions of how we can analyze, integrate, understand, manage, and present all of this disparate data. This is followed by a chapter on the topic of how we can manage the complex task of collaboration across the national, cultural, and disciplinary divides that separate us and inhibit our successful collaboration. The final chapter seeks to present our final conclusions, some consideration of what we have attempted, some specific cautions and recommendations, and thoughts about the future of Historical Ecology and where this is all going.

We recognize that no such volume can be completely comprehensive, and that important subjects have not been included, due to several reasons. We also are very aware that any such work is instantly out of date as soon as it is published, and that these fields are evolving rapidly. But we also recognize that these are opportunities for other writers in the future, or perhaps future editions if this work. We apologize in advance if we have failed to include some of what you consider to be key aspects of these subjects, or if our treatments differ from yours. We urge you to respond to and critique (constructively) our work and look forward to engaging with the broader community on these subjects. We have made our best effort to present the information in a fair and reasonable way and any factual errors are unintentional and are the responsibility of the individual authors and editors.

Ultimately, we hope that this work will broadly enhance skills and enlarge the number of researchers using these tools, and possibly bring new and enhanced approaches to this important area of research. We also hope that this work will encourage and enable people around the world, representing many disciplines, to begin new research projects and activities, and to reach out and form new collaborations across disciplines, as well as to consider adding additional techniques and approaches to their ongoing work. We hope that this will make a good textbook for these subjects, and that more students around the world will begin their own work by reading this volume. In the end, we hope you find this useful and even enjoyable to read as well. For consistency, we have chosen to capitalize Historical Ecology throughout the volume.

Introduction by Anna Westin

When I started my university education some thirty years ago, there were no interdisciplinary programs involving ecology. Interdisciplinary perspectives were basically missing during my entire training in biology, with one exception. During a course in nature conservation, the teachers acknowledged that conservation issues needed to be dealt with from a society perspective in order to succeed. We also had one lecture about Historical Ecology in cultural landscapes. Not long after that, I started my masters thesis and chose to focus on the succession of plants in abandoned farmlands at a Swedish military training area. In order to know where the hay meadows and arable land had been, I had to consult historical maps. I soon realized I had to take a course in Agrarian History. My eyes were finally opened. From that moment, I have never been able to separate ecology and human history. Furthermore, I felt that I had been withheld from one of the most essential perspectives of ecology, the historical land use, during my entire biology training. If a book like this had existed, it would have made a great difference for me. Imagine one book, introducing the most important methods and sources in Historical Ecology. That would have been a dream to me.

After a year employed to work with applied nature conservation (again relying on the combination of Biology and History I had the chance to write my doctoral thesis in Agrarian History. My subject this time was the history of semi-natural pastures of conservation interest. This enabled me to get well acquainted with historical sources, source criticism, and what kinds of questions that nature conservation wants to know, that historical documents can actually answer. Other PhD students and researchers did biological field work, interviewing farmers, and testing different grazing models. Together we tried to answer the bigger question on how to obtain successful conservation methods, which would be good for biodiversity, the farmer and the grazing animals. I remember the long and interesting discussions on methods and terms. There were many misunderstandings, most of them due to lack of understanding of each other's research methods, theoretical approaches and terminology. My learning from this time is that there is always room for "stupid" questions, everyone is a beginner somewhere and nobody can be an expert in every field. With training and a wide interest in life you can manage to become a good researcher in both ecology and in history, at least in some subsection of ecology and history. But it may be equally (or even more) fruitful to stay an open-minded expert. Deep roots into one discipline, and a sincere interest in other disciplines, is a great foundation for interdisciplinary collaboration. In order to save some time and frustration, it is useful to have some basic knowledge about the fields and methods you want to work with. If you are going to build a house, you need the expertise from plumbers, house constructors, electricians and carpenters. There is no need to manage all the skills yourself, but you need to manage the communication with the different people you work with. I also find that the skill of understanding other people's perspectives and interests is a very loving way to approach other people in every possible context, academic or non-academic.

It is my sincere belief that this book will facilitate communication between scholars of different disciplines in various ways. For those who have not yet chosen their field of expertise, it will give an overview of some of the different interesting options within Historical Ecology. For those who want to collaborate with others, this is a great start to understand what can be done, who to take contact with and what more you need to learn to facilitate cooperation. Personally, I believe that we are all on a "big" mission on this Earth, which is to create a beautiful world together, built on mutual understanding, respect and caring for each other and the non-human world. If this book can be a door opener for anyone to wider and nonjudgmental perspectives, via the academic path, it would warm my heart.

Introduction by Elizabeth Jones

I have always been interested in interdisciplinary studies. As an undergraduate pursuing a degree in history, I focused on interdisciplinary medieval studies, learning about the history, literature, technology, science, art, music, and drama of the Middle Ages. I later went on to earn a graduate minor in interdisciplinary Medieval Studies. Because I was most interested in the everyday life of the past, I switched from history to archaeology in my postgraduate studies, earning a Ph.D. in historical anthropology. I discovered that archaeology itself is basically interdisciplinary, with many subdisciplines and specialists working together as a team on any excavation. Through archaeology I saw the many benefits of people with different methodological expertise and intellectual approaches working together on the same questions. The interaction of people with their environment has become an essential question in archaeology, and when I became interested in the history of small farms in Burgundy, it was a short step to using Historical Ecology as the most productive framework in which to answer my questions about the behavior and practices of these long-ago farming communities.

I was very fortunate to be mentored by one the pioneers in Historical Ecology, Carole Crumley, who showed me that understanding the past successes and failures in farming in different environments, climatic regimes, and social, economic and political contexts can be an essential tool in providing models and alternative ideas for building sustainable, resilient farming going forward. I believe that our current situation of rapid climate change, rapid changes in technology, the increasing globalization of the economy, and sociopolitical instability have caused issues of sustainability, resilience, and the future to be a concern of almost every scholar. Historical Ecology provides a means for scholars from most any discipline to apply their expertise in addressing these big questions through creating a better understanding of past human-environment relationships.

If you are new to Historical Ecology, we hope that by reading this book you will see how you can apply your own scholarly expertise, even if we don't cover a specific example of what you do. By seeing how different types of studies and data can be integrated, it may stimulate you to see how your own work could contribute to such studies. If you are already working within the perspective and framework of Historical Ecology, hopefully this book will increase your understanding of how other disciplines and approaches might be integrated with your own. It is our hope that this book will inspire new kinds of integrations of perspectives, methods, and data. Historical Ecology is a dynamic and evolving field of study to which all of us can contribute.

ACKNOWLEDGMENTS

We would like to acknowledge the several people who were instrumental in helping us to complete this work.

First of all, we acknowledge Carole Crumley and the others who began this journey into Historical Ecology, not knowing where it would lead or how it would unfold. Along with her we also acknowledge the other researchers and thinkers from around the world who have pushed the concept of Historical Ecology forward. There are many, and we acknowledge their many contributions. We also thank all the contributors and authors, for their time, thoughts, and effort to make this book a reality. We are all very busy, and it has taken a significant amount of time and effort to put this together. We the editors thank them all for their contributions.

Secondly, we express our sincere appreciation to the many people in our various study areas who have welcomed us, fed us, taught us, walked with us, and assisted us in our work. This type of research cannot be conducted successfully without the generous collaboration and support of the local people who live in and know so well their own backyards which are our research areas to us. Their kind and welcoming generosity is gratefully acknowledged.

We also thank the CBM for agreeing to publish this work, and for their editorial assistance, support, and encouragement.

We are grateful to Dr. Seth Murray of N.C. State University, who participated very much in the planning and development of this volume, and whose involvement was an important element of this work being published.

We also thank all the people who walked before us on this Earth, who lived their lives in that close or distant past which we long to learn more about. We are grateful for the biocultural diversity they created, intentionally and unintentionally, through their intimate relationship with local ecosystems, and that they in various ways created the different sources, the keys to historical knowledge, that we now find in archives, landscapes and the Internet. We acknowledge their presence.

And finally, we thank you, the reader, for your time and interest in reading our work. Our goal is to share what we have learned in a straight-forward and useful way, and we hope that you will benefit from this considerable task we have embarked upon. Please feel free to contact the editors with your views, ideas, and suggestions. Today's actions will become the history for future generations.

Scott Madry, Anna Westin, and Elizabeth Jones
2024

CHAPTER 1

A BRIEF INTRODUCTION TO HISTORICAL ECOLOGY

WHAT IT IS, WHERE IT COMES FROM, AND HOW IT CAN BE DONE

SCOTT MADRY

Figure 1.1. The Burgundy, France landscape, viewed from an ancient hillfort rampart. Image by S. Madry

This first chapter will present a very broad overview of Historical Ecology. It will include a brief review of the history and development of the discipline, including several of the main persons who were involved in the formation and development of this relatively new field of research. Then, some useful information about what it is, including the fact that there are many different disciplinary and national perspectives and as many definitions. This will be followed by useful information regarding how Historical Ecology research, in general, is conducted. Finally, we present some of the other books and book series that are available today for your further reading and learning about the subject. This is not a comprehensive or complete presentation of all things related to Historical Ecology, that would be a large book of its own, but rather a general overview which will set the stage for the following chapters which relate in detail to individual aspects of such research. So let us now set the stage.

What is Historical Ecology?

In its broadest sense, Historical Ecology is a relatively recent interdisciplinary field of research that focuses upon the relationships between humans (as individuals, communities, and societies), and their environments at all scales, and how these relationships change dynamically over time. It explicitly includes how people and their environments affect each other and live in a dynamic synergy together. Historical Ecology emerged as an independent and distinct field of study in the later 20th century and has since grown in breadth and importance as researchers and scholars from many disciplines and perspectives have come to understand both the complexity and importance of these human/environmental interactions over time. The long-term interactive dynamics of humans, ecosystems, and landscapes must be considered in an explicitly transdisciplinary context, and our understanding of these relationships have important current social, policy, economic, and political ramifications. By transdisciplinary, we mean not only does it involve researchers from several different academic disciplines and traditions working together, but also people outside the traditional academic community participating as well.

The Historical Development of Historical Ecology

The roots of this field can be traced back to early work of many individual geographers, archaeologists, historians, and others who were interested, coming from their own disciplinary perspectives, in understanding and reconstructing past landscapes and the role of humans in these. (For a more comprehensive treatment of the origins of Historical Ecology, from a British perspective, see Szabó 2014). Early research focused on the study of ancient civilizations such as ancient Rome and the Mayan and Incan empires in America. Researchers began to ask relevant questions about the role of humans and their environments in the rise and fall of civilizations and in both dominating and being impacted by the natural environments in which they lived. In the mid 20th century, Historical Ecology began to emerge as an independent field of study, and scholars including the American geographer Carl. O. Sauer published on the importance of ‘ cultural landscapes ’ and the role of humans in creating and shaping these over time (Sauer 1941, 1956). His ideas laid important groundwork leading to the integration of previously separate historical and ecological perspectives and research.

The theoretical development of Historical Ecology is also closely linked to the French Annales School, named after the French journal *Annales d'Histoire Economique et Sociale* or "Annals of Economic and Social History". This academic journal was founded in Strasbourg, France in 1929 by French historians Lucien Febvre and Marc Bloch. Their concept of interrelated scales of time in historical analysis, including the ideas of the *longue durée* (long-term trends and cycles] and *conjoncture* (particular conditions) was later expanded under the leadership of François Braudel. The Annales School proposed a new type of historical research, one that was less concerned with great leaders and pivotal events, and more focused on the long-term and complex interplay of demographics, technology, transportation, agriculture, and climate, among other factors. It also was more focused on the lives of common people and their relationship with their environment. (Braudel 1980; Burguiere 2006; Burke 1990; Knapp 1992).

In the 1960s and 1970s, ecological perspectives and issues came to be seen as vital societal and academic questions, and we also saw the initial development of what we today refer to as interdisciplinary approaches which were key to the development of Historical Ecology. Researchers from many individual disciplines including anthropology, archaeology, ecology, geography, and history began to collaborate in the analysis of long-term environmental changes over time and the impacts of human activities in these (Risser 1987). These and other researchers began to draw upon the perspectives and work of landscape ecology, a fairly recent subdiscipline within ecology, which focuses on the spatial arrangements within ecosystems (MacArthur and Wilson, 1967, Neef 1967, Sauer 1971). These researchers pioneered the application of palaeoecological methods, including the collection and analysis of pollen records, sediment cores, and dendrochronology (tree ring) data to reconstruct past environments and ecosystems over many hundreds or even thousands of years (Berggren 1974). Archaeologists, interested in similar issues, quickly adopted and integrated these new techniques and data into their work and developed working relationships with these ecologists (Tuttle 1975) and added an explicit human culture/environment perspective.

In recent decades, there has been a growing interest and emphasis on the integration of indigenous knowledge and Traditional Ecological Knowledge (TEK) into such research. This brought into Historical Ecology the important perspective that local individuals and communities often possess unique insights into the local ecosystems within which they live, and that these insights can inform historical and current land use management issues. Also recently, Historical Ecology research and perspectives have gained relevance in environmental policy and conservation and land use management. By better understanding the complex relationships between peoples and their environments, and how these change over time due to both human and natural causes, policy makers and land managers can, hopefully, make more informed decisions about land use, land restoration, conservation, and related issues which face us all. It also potentially brings a greater public awareness of our relationship with and our potential impacts upon our environment going forward.

Major Figures in the development of Historical Ecology

Historical Ecology has been organically developed over the past century by a very diverse and international group of scholars from many different academic disciplines, cultures, and perspectives. These include anthropology, archaeology, ecology, history, geography, and more. In this section we will present just a few of the many major figures whose work has shaped and defined Historical Ecology. This is by no means a comprehensive list, and we sincerely apologize in advance to those worthies who are not included in this very brief list, which only touches the surface and is intended only to provide a guide to those unfamiliar with the subject. We cite only a few of these author's many relevant works. To be as unbiased as possible, we present them in alphabetical and not chronological order.

William L. Balée. He is an anthropologist best known for his important work in Historical Ecology, particularly his work on indigenous peoples of the Amazon rainforest (Balée 1994, Balée and Erickson 2006). He stressed the importance of local and indigenous knowledge and practices as a means of understanding and explaining complex historical ecosystem dynamics (Balée 2012). His work has shaped and contributed to Historical Ecology in stressing the profound importance of how local communities have interacted with and shaped their environments over time frames of thousands of years. Some of his contributions include the concept of 'cultural landscapes' in his Amazonian research, where he emphasized that indigenous communities actively manage and shape their environments through the use of fire, agriculture, and forestry; which have, in turn, created diverse and productive ecosystems that directly reflect the cultural and environmental knowledge of the local inhabitants. He challenged the concept of a 'pristine' pre-Columbian rainforest, proposing instead that local peoples had created and managed a rich diversity of ecosystems that supported them, thus challenging the prevalent concept that humans were primarily a destructive force to the rainforest. His work had a long-term perspective over centuries or longer and included the analysis of both archaeology and historical records to support his conclusions. He also recognized the vital nature of Traditional Ecological Knowledge (TEK) and supported the integration of this into current practical conservation and land use management contexts. His work has been seen as having larger implications about considerations of sustainable resource management in the Amazon and beyond and is seen as providing important insights into more sustainable and resilient approaches to modern ecological and conservation practices. His work was important for the nuanced level of understanding of dynamic, complex, and ever-changing relationships between humans, their cultures, and their local environments over time, and the importance of TEK in both conceptual and practical contexts (Balée 2013).

William Cronon is an historian, best known for his influential role in the fields of environmental history and Historical Ecology (Cronon 1990, Cronon 1996, Cronon et al. 1996). His work has shaped how historians, in particular, have seen the complexity of the relationship between human societies and their environments over time. His important book "Changes in the Land: Indians, Colonists, and the Ecology of New England" (Cronon 1983) examined the ecological impacts and transformation of New England over the timeframe ranging from the pre-colonial era into the early colonial period. He demonstrated that the radically different approaches to the land by the native Americans and European colonists drove significant and drastic ecological changes in the region. This book is considered to be a seminal work in the development of the field of environmental history. In it, he placed a new emphasis on the complex and dynamic relationship between the different human occupants of the land and their environment. He stressed that it was vital that the study of history and historical research and documents be seen within the broader context of how human societies have both shaped and have been shaped by their environment. He introduced the concept of the 'unfolding landscape' and the importance of understanding how landscapes change over time due to both natural and human causes. He stressed the importance of incorporating the temporal perspective in historical analysis. He was also a strong advocate for an interdisciplinary perspective in historical analysis, drawing from many disciplines which today make up Historical Ecology. He argued that historians must include the perspectives and insights of scholars from many disciplines, and his work had a lasting influence on both the discipline of history but also environmental studies, and firmly placed ecological perspectives within the study of history. As the president of the American Historical Association, he had a strong influence on the development of the discipline and the direction of research of many young scholars. He played an important role to better understand the importance of the role of the environment and ecology on historical studies, and the need for interdisciplinary perspectives within the discipline of history.

Carole Crumley is a prominent anthropologist and archaeologist, who has made significant contributions to both the method and theory of Historical Ecology (Crumley 1994, 2017, 2021). Full disclosure- she was the Ph.D. advisor for the author of this chapter and two of this volume's editors, and remains today a colleague and friend. Her influential early papers and theoretical work in Historical Ecology have shaped in important ways the development of Historical Ecology and the ways that both academics and land use managers have conceptualized the study of human/environmental interactions over time. Her ground-breaking long-term research in the Burgundy region of France in the 1970's, which is continued to this day by the authors, laid much of the framework for Historical Ecology in the context of anthropology and landscape archaeology (Crumley 1987). One of her early papers (Crumley 1994) is frequently cited as a key foundational work in Historical Ecology. In this paper, Crumley presents the vital importance of integrating together cultural and ecological aspects in order to comprehend how past societies both shaped and were shaped by their environments, and how these changed over time. While this paper may not have been the first use of the term Historical Ecology in the literature, it played a major role in shaping and forming the concepts of an implicitly interdisciplinary field of study which is Historical Ecology. Her works have several common themes, including the importance of an interdisciplinary/transdisciplinary research approach. Very early on, she advocated for the importance of bringing together scholars from many disciplines to, together, investigate the long-term changes in the interaction between humans and their environments. She not only advocated for this but pursued it in a practical sense.

Perhaps her key contributions have been theoretical in nature, including the development of the concepts of heterarchy (Crumley 1995, 2015) and resilience (Crumley et al. 2018) in this context. Heterarchy refers to a system, either cultural or natural, which can be described as a non-hierarchical or a decentralized type of structure. In a heterarchical system, multiple power centers can exist, and decision making occurs in complex and distributed ways. These can exist in social, political, biological, and other complex systems. Resilience, in the Historical Ecology context, refers to the capacity of both human and natural systems to withstand and adapt to disturbances in the system. Her work has explored how and why some past human societies have managed to maintain resilience over time and the importance of this. Crumley's continuing work has had a lasting impact on Historical Ecology theory, providing a theoretical context for a holistic and transdisciplinary approach to the long-term analysis of human societies, their technologies and social organization, and the natural environment with which they maintain a synergistic relationship.

R. Lee Lyman is an archaeologist working in the subfield of zooarchaeology. He has combined and integrated archaeology and ecology to study human interactions with past environments, and how these have changed, using the study of animal remains located within archaeological sites (Lyman 1994, 2008). These analyses have informed work relating to human subsistence strategies, reconstruction of past environments, and the impacts of humans on historical ecosystems. His contributions revolve around both the statistical analysis of faunal materials within archaeological assemblages, and also his innovative ethnoarchaeological work, including the study of contemporary human interactions with their environment, which have been useful in interpreting his zooarchaeological data. These have been used to conduct Historical Ecology research by integrating these and other related data to assemble a more complete understanding of past human and ecological interactions and relationships (Lyman 2006). His work has stressed the importance of careful quantitative analysis of zooarchaeological remains, informed by ethnoarchaeology, ethnography, and historical records, to better reconstruct prehistoric hunting and fishing strategies within their larger ecological contexts.

Paul. S. Martin (1928-2010) was an American geoscientist, most well-known for his contributions to understanding the ecological history of North America, specifically the now-extinct megafauna and their interactions with the natural environment and early human populations. He developed the 'overkill hypothesis' in the 1960's, proposing that the North American megafauna were driven to extinction by overhunting by humans quickly after their arrival on the continent (Martin 1973, 2005, Martin and Klein 1984). His work involved early research on paleoecology, the analysis of past ecological systems, and he used multiple disparate data sources, including field work, radiocarbon dating, fossil analysis, and geological data, to reconstruct a broad ecological history of the continent in the Pleistocene-Holocene transition period where the most recent Ice Age ended, and the warmer modern era began. His work led to him becoming a strong advocate for modern conservation efforts, using his research to propose more responsible environmental practices with an emphasis on biodiversity preservation (Donlan and Martin 2004). He mentored many students and others who have gone on to make significant contributions and has had an important impact on Historical Ecology in terms of using disparate datasets to better understand the complex relationships between humans and their environment, including animals, in the past.

Charles Redman is the Founding Director of the School of Sustainability, College of Global Futures, at Arizona State University. He is an archaeologist and anthropologist whose work has been important in the development of ideas regarding how human activities have shaped past landscapes and ecosystems, and how such knowledge can be used to derive insights regarding current environmental and policy issues we face today (Redman 1999, 2012, Van der Leeuw & Redman 2002). He has had a major impact on the development of Historical Ecology and was instrumental in the development of many of the aspects of the field. These include a commitment to an interdisciplinary approach to these issues and taking a very long-term perspective. Some of his research covers over a thousand years, providing a deep view of how human societies and ecosystems and their interactions evolved over long time frames. He has worked extensively in past urban environments, investigating how the development and evolution of human urban contexts impact the environment and the management of resources in the context of sustainability and resilience (Grimm et al. 2000, 2008). He has also sought to bring the knowledge of past ecological factors to contemporary contexts. He is a proponent of the strong coupling of social and ecological systems and has focused much effort on addressing current environmental issues using his Historical Ecology research and of the role of resilience theory in these studies (Redman 2005, Redman & Kinzig 2003).

Carl Troll (1899-1975) was a German landscape ecologist and geographer whose work has had a significant impact on the study of the ecological dynamics of landscapes over time. Troll was influenced by major German geographers such as Christaller, and is considered to be one of the major early forces in the development of the field of landscape ecology, a major component of Historical Ecology and itself an important interdisciplinary activity. His work emphasized the complexity of landscapes and their ecological context, as well as the importance and complexity of the human/landscape relationship (Troll 1960). He was an early researcher into the important role of climate and climate studies in this work, as well as conducting detailed analysis of vegetation zones and landforms, especially in mountainous environments (Troll et al. 1950, Troll 1968). He expanded this to include the impacts of human activities, including agriculture, forestry, land use and other factors, and was an early proponent of modern sustainable land use practices, based on his research. He was an early innovator in the use of aerial photography for landscape research and conducted work in Asia, South America, and Europe. He did innovative work on the Inca empire using aerial photos and a variety of integrated techniques. His very important book Geoecology (Troll 1950) is considered to be a key work in the early formation of landscape ecology concepts and influenced the development of modern ecology and geography. His body of work, which extended broadly, was key to the development of holistic and integrated theories in Historical Ecology.

As stated previously, these are only a few of the early innovators who were involved in the development of Historical Ecology, but they show the breadth and diversity of the backgrounds, interests, and skills over the decades that created what we call Historical Ecology today. There were, and are, many others, including many young researchers who today are conducting innovative and important work to expand and extend the boundaries of the current practice. You should conduct your own literature review and discover some of the other innovators who have shaped the discipline. We present some of the currently available major Historical Ecology books at the end of this chapter.

Description of Historical Ecology

Today, Historical Ecology is a well-recognized but still growing academic and practical interdisciplinary research domain crossing many traditional academic disciplines and perspectives. It has gained a theoretical and practical maturity both within academic and natural resource management and policy practitioners, while it continues to grow and evolve. Historical Ecology faces many challenges, including the need to address many environmental changes and the pressing need for sustainable resource management by an ever-growing human population. Many academic researchers and land use managers today are using historical data derived from many sources to provide insights to better inform our need for effective strategies for the mitigation of the many complex issues we face today, including global climate change, the preservation of biodiversity, ecological restorations, the protection of indigenous populations, and many more.

Overall, Historical Ecology has evolved quite rapidly from a small niche area of research in a few disciplines into a mature and dynamic research domain that has great potential. It consists of both theoretical and methodological components, and, if harnessed appropriately, can assist us in both conceptual and practical ways to better comprehend the complex relationships between humans and our environments over time. The implicit transdisciplinary nature of this work, a mixture of multiple techniques and technical data, along with its emphasis on the long-term perspectives, make it a valuable suite of tools for addressing many of the pressing environmental and social issues of our times, as well as providing new knowledge about our ancient past.

Definitions

It is interesting to note that there is no clearly agreed upon idea of what Historical Ecology actually is, and evidence of this is the fact that there are many differing definitions of Historical Ecology in the literature. This is partly due to the fact that there were so many early researchers involved, each of whom came from different academic disciplines, nations, and scholarly perspectives and traditions. In fact, Szabó includes a list of no fewer than 35 different definitions in his overview of the historical development of the field, with dates ranging from 1948 to 2013 (Szabó 2014). It is clear that there is no single definition, or even common understanding, of what Historical Ecology is.

Partly in jest, I asked ChatGPT to provide a definition of Historical Ecology in October of 2023, and this is what 'it' replied:

> Historical ecology is an interdisciplinary field of study that focuses on the interaction between human societies and their environments over time. It seeks to understand how ecosystems have changed and evolved due to human activities and how human cultures and societies have been shaped by their relationships with the natural world throughout history. This field combines elements of ecology, archaeology, anthropology, geography, history, and other disciplines to reconstruct past environments, analyze the impact of human actions on these environments, and explore the reciprocal influence of the environment on human societies. Historical ecologists often use a variety of sources, including written records, archaeological evidence, GIS, and modern and historical ecological data, to piece together the complex and dynamic relationships between humans and their environments across different time periods and geographic regions (ChatGPT accessed Oct 2, 2023).

Not bad… make it 36 and counting. What is your definition? What might it be in 5 years? Who gets to decide?

One of the interesting reasons there are so many definitions is that Historical Ecology developed roughly simultaneously in several separate disciplines, cultures, and academic literatures. Perhaps a larger issue is that, even today, there is no general agreement on the fundamental question of what, exactly, Historical Ecology does. Is it a perspective or viewpoint, a scientific theory or a connected set of theories, an academic research framework, a research design framework, a practical applied science, or a "program"? This is also an indication that the field is still emerging and continues to grow and is dynamic, which is a good thing. It also means that you, the reader, can play a part in continuing to define and create what this will all become.

Basic assumptions of Historical Ecology

Even if we cannot decide on a single definition, there are several fundamental assumptions about what Historical Ecology is. Among these can be included the following (others might well come up with a different list). Perhaps first is the assumption that there is a dialectical relationship between humans and their environment through time (Brady 2006). Each impacts and is in turn impacted by the other. They both exist in a dynamic and constantly shifting dance, and any action by one causes other changes in the other in a never ending symbiotic relationship. Secondly, it is the landscape, however defined, that is the record of the past relationships between humans and their environment, and that landscape provides a focus for the interdisciplinary study of that relationship today and in the future (Wu 2000). The landscape is the unit of analysis, broadly defined, in Historical Ecology. Thirdly, that landscape includes both the "natural" and the "built" or "human modified" aspects, and that these, in the past and today, are intimately intertwined. There are no completely natural landscapes, environments, or ecosystems on Earth anymore—all have been shaped to some degree by human activity. So we humans are an integral part of every ecosystem, and humans should not be always viewed as intrusive or a negative factor in their ecosystem. It is more complicated than that. Human actions are not only negative impacts upon the land, and our actions are symbiotic and can also be positive in their impacts.

On the social side, we humans and our conceptions of their environment are just as key to understanding human/environment relationships as the physical environmental factors. Please see chapter 3 on Biological Cultural Heritage, for a more complete consideration of this important perspective, but in Historical Ecology, it is not the environment OR the human footprint, but both together. One important aspect of this is the domain of Traditional Ecological Knowledge, or TEK. This traditional knowledge about the environment and how to utilize it, how to extract resources and how to sustain both the people and environment, is just as important as purely quantitative or scientific knowledge about the landscape and should be accorded the same respect in our work. Please see chapter 10 on Engaged Historical Ecology, for a more complete treatment of this important topic and perspective.

The past relationships between humans and their environments that resulted in landscapes provide contexts and constraints for human activity in the past, present and the future. Our study of the history of landscapes, environments, ecosystems and the human role in their formation can inform the present and future (especially for modeling) with insights, correlations, a range of possibilities, and suggestions for specific research questions. There are powerful lessons to be learned from Historical Ecology research, beyond the academic aspects of our work, and we must be open to expanding and enhancing the practical applications of our work to better inform decision-making regarding landscape preservation, ecological restoration, environmental modeling, and the protection of indigenous peoples around the world. We must be ready and able to make our academic research available and useful to address the many, complex issues facing our world, today and in the future (Egan & Howell 2005).

We should also consider that the Earth sciences, human sciences, social sciences, and traditional knowledge must be fully integrated to achieve a more fulsome understanding of the processes involved in landscape formation and the functioning of ecosystems. This is a key goal of this volume, to attempt to provide practical and useful guides to more fully understand and integrate these different approaches and data. The data that we generate and analyze are a vital aspect of this work, and this volume seeks to present many, not by any means all, of the types of data and analysis that forms the core of this work. Historical documents, maps, Geographic Information Systems (GIS), remote sensing imagery, GNSS satellite positioning, data analytics, and more are often at the core of our work, and we present case studies and examples in this volume.

This requires truly transdisciplinary research designs, data, and analysis. And this is essential for understanding the complexity of landscapes and ecosystems and their historical development. Real interdisciplinary and transdisciplinary research requires a multi-scalar, multi-temporal, multi-disciplinary, and multi-data analysis approach in order to integrate the various datasets that reflect these scales, and to evaluate the interaction of the processes operating at these different temporal and spatial scales. Such truly transdisciplinary research requires extensive collaboration both among the researchers involved, their data and analysis, and with the other stakeholders contributing to and affected by the research. This volume is dedicated to this important goal.

Beyond this, Historical Ecologists have a responsibility to share their knowledge and understandings with contemporary communities, decision-makers, and governmental entities to contribute to creating sustainable environments going forward.

How is Historical Ecology research conducted?

This book is a guide, a guide to the practical aspects of conducting Historical Ecology research. But before we go into the details that make up the following chapters of this volume, we should take a brief look at the general process of how such research is conducted. Each project is unique and different, but in a general order, a Historical Ecology project consists of the following:

- Research formulation- Specific research questions and hypotheses are identified, a study area is chosen, spatial and temporal timeframes are defined, and team members and their roles are identified. Funding sources, budgets, and organizational aspects, including the duration of the study are defined.
- Literature Review- A full literature review is conducted to identify the current state of practice and to ensure that the questions to be addressed are current and relevant.
- Data Collection- Data of all types are collected and placed into the appropriate data structures for analysis. This includes field work, library and document research, archaeological surveys and excavation, ecological and palaeoecological data collection, oral histories and ethnographic interviews, and more.
- Data Analysis- All of these above listed data are then analyzed. Statistical analysis is conducted to identify patterns and correlations. GIS, remote sensing, GPS, and other systems are used to map and analyze spatial and temporal patterns. Researchers internally share the results of their individual research components to the group and then compare and contrast the various data results within the team.
- Data Synthesis- Members of the team seek to integrate and synthesize their results into an overall, coherent narrative of the patterns of continuity and change in the study area over space and time, and present the interactions of the human societies and the environment in the context of the research design.
- Data Interpretation- The team then develops a set of theories, interpretations, and analysis based on their results. Hypotheses that were proposed are tested, and timelines, maps, and visualizations are created to illustrate the results. Conclusions are reached, and new theories or hypotheses are presented

to the broader academic community for their consideration. Future directions of research based on this project are presented, both for the project participants and others.

- Publication and Public Communication- Results are shared in academic peer review journals, books, conferences, and other publications and venues, preferable Open Source outlets. Other popular publications and other media, including social media, websites, public presentations, museum exhibits, and other media can be used to present the results as broadly as possible.
- Data Conservation- The data, both the raw data and analyzed data should be properly conserved using a digital archiving system, so that others can use the data in the future.
- Conservation and land use management implications- Research in Historical Ecology often has important, practical implications for improved land use and land cover management, habitat protection, sustainable land practices, ecosystem restoration and management, and the protection of endangered species and indigenous peoples. Consideration should be taken for these important activities and steps taken to maximize the benefits of the research for the local people and land managers.
- Lessons Learned- At the end of the project, the team should consider lessons learned, and what went well and what did not. Honest consideration of how to improve all aspects of the work in the future should be taken and, very importantly, shared so that others can benefit from your experience.

Current Historical Ecology publications and series

There are multiple academic publications using a Historical Ecology framework, and these are presented throughout this volume. Some of the main publications that you might consider reading include the following:

The Rutledge series New Frontiers in Historical Ecology has produced seven books in their series, all of which are very useful.

https://www.routledge.com/New-Frontiers-in-Historical-Ecology/book-series/LCPNFHistoricalEcology#:~:text=This%20book%20offers%20a%20comparative,throughout%20the%20region%20and%20…

The Historical Ecology Handbook: A Restorationis's Guide to Reference Ecosystems Edited by Dave Egan and Evelyn A. Howell 2001 Island Press. 445 pagers, was the first consideration of this topic, largely focused on North America and with a strong restoration ecology perspective.

https://www.google.com/books/edition/The_Historical_Ecology_Handbook/hRu8BwAAQBAJ?hl=en&gbpv=1&dq=+collaborate+effectively+in+historical+ecology&pg=PR7&printsec=frontcover

Advances in Historical Ecology, William Bailee, editor 2002 448 pages Columbia University Press

Issues and Concepts in: Historical Ecology: The Past and future of Landscapes and Regions eds. 2017 Carole Crumley, Anna Westin and Tommy Lennartsson. Cambridge University Press. Pp. 240-275.

The De Gruyter Historical Ecology series https://www.degruyter.com/serial/cuphes-b/html?lang=en

Material Evidence: Learning from Archaeological Practice https://www.material-evidence.net/contents.htm

Recently, Crumley and Bailée have published a review of Historical Ecology research and publications (Crumley and Bailée 2024) which reviews the major foundational texts and methods, and does a global review of research by categories such as forests, tropics, islands, etc. It concludeds with an overview of appliced Historical Ecology and heritage management. The work is available with a subscription to the online Oxford Bibliographies series.

Also in 2024, Aarón Moises Santana-Cordero, Péter Szabò, Matthias Bürgi, and Chelsey Geralda Armstrong have published a comprehensive overview of Historical Ecology research (Santana-Cordero et.al 2024) which will be of interest to readers of this volume. They conducted a Google Scholar search for the words 'historical ecology' between 2015 and 2019 which returned some 7,200 entries. This was reduced to 544 papers from between 1981 and 2019 derived from the SCOPUS database (Elsevier). These papers were analyzed by study area, study period, sources, methods and recommendations, with their results presented using various charts and graphs. It makes very good reading for those interested in the current status of Historical Ecology reseach.

Conclusions

Hopefully, this introductory chapter has provided a very broad overview of what Historical Ecology is, where it came from, and how it is conducted. Our intention is only to set the stage for what follows, and there is much more to learn than was presented here as a simple introduction. Now let us proceed to the individual chapters covering in much more detail many of the key individual components of this important and interesting work.

The individual chapters presented in this book are a sampling of the kinds of research that can be conducted within the Historical Ecology framework. We seek to provide the reader with a practical and useful introduction to many of the tools that are included in such research. It is not comprehensive, and we cannot cover all aspects or approaches to this work, but we can provide a sufficient number to guide the reader to be able to begin or expand their own work. We hope that the following chapters, each presenting a specific topic or technique in detail, will assist you in your own journey.

References

Balée, W. L. (1994). Footprints of the forest: Ka'apor ethnobotany-the historical ecology of plant utilization by an Amazonian people. Columbia University Press.

Balée, W. L. (Ed.). (2012). Advances in historical ecology. Columbia University Press.

Balée, W. (2013). Cultural forests of the Amazon: a historical ecology of people and their landscapes. University of Alabama Press.

Balée, W. L., & Erickson, C. L. (2006). Time and complexity in historical ecology studies in the neotropical lowlands. Columbia University Press.

Berggren, W. A. (1974). Late Paleocene: Early Eocene Benthonic Foraminiferal Biostratigraphy and Paleoecology of

Rockall Bank. Micropaleontology, 426-448.

Brady, Emily. The aesthetics of agricultural landscapes and the relationship between humans and nature." Ethics, Place and Environment 9, no. 1 (2006): 1-19.

Braudel, F. (1980) History and the social sciences: The Longue Durée. In: On history. University of Chicago Press, Chicago, 22-54

Burguière, A. (2006) L'École des annales: une histoire intellectuelle. Odile Jacob, Paris

Burke, P. (1990) The French historical revolution: The Annales School, 1929-1989. Stanford University Press, Stanford, CA

Cronon, W. (1983) Changes in the Land: Indians, Colonists, and the Ecology of New England. New York: Hill & Wang.

Cronon, W. (1990). Modes of prophecy and production: placing nature in history. The Journal of American History, 76(4), 1122-1131.

Cronon, W. (Ed.). (1996). Uncommon ground: Rethinking the human place in nature. WW Norton & Company.

Cronon, W., Dunlap, T. R., & Juca Forest, T. (1996). Environmental History. The trouble with wilderness: or, getting back to the wrong nature, 1, 7-28.

Crumley, C. L. (1987). Historical ecology. Regional dynamics: Burgundian landscapes in historical perspective, 237-264.

Crumley, C. L. (1995). Heterarchy and the analysis of complex societies. Archeological papers of the American anthropological association, 6(1), 1-5.

Crumley, C. L. (2015). Heterarchy. Emerging trends in the social and behavioral sciences: An interdisciplinary, searchable, and linkable resource, 1-14.

Crumley, C. L. (2017). Historical ecology and the study of landscape. Landscape Research, 42(sup1), S65-S73.

Crumley C. L. (1994) Historical Ecology: Cultural Knowledge and Changing Landscapes (School for Advanced Research Advanced Seminar Series).

Crumley, C. L. (2021). Historical Ecology: A robust bridge between archaeology and ecology. Sustainability, 13 (15), 8210.

Crumley, C. L. and W. Bailée (2024). Approaches and Issues in Historical Ecology in: Oxford Bibliographics https://www.oxfordbibliographies.com/display/document/obo-9780199830060/obo-9780199830060-0250.xml

Crumley, C. L., Lennartsson, T., & Westin, A. (Eds.). (2018). Issues and concepts in historical ecology: The past and future of landscapes and regions. Cambridge University Press.

Donlan, C. J., & Martin, P. S. (2004). Role of ecological history in invasive species management and conservation. Conservation Biology, 18(1), 267-269.

Egan, D., & Howell, E. A. (Eds.). (2005). The historical ecology handbook: a restorationist's guide to reference ecosystems. Island Press.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. science, 319(5864), 756-760.

Grimm, N. B., Grove, J. G., Pickett, S. T., & Redman, C. L. (2000). Integrated approaches to long-term studies of urban ecological systems: Urban ecological systems present multiple challenges to ecologists—Pervasive human impact and extreme heterogeneity of cities, and the need to integrate social and ecological approaches, concepts, and theory. BioScience, 50(7), 571-584.

Knapp, A.B. (1992) Archaeology, Annales, and ethnohistory. Cambridge University Press, Cambridge

Lyman, R. L. (1994). Quantitative units and terminology in zooarchaeology. American Antiquity, 59(1), 36-71.

Lyman, R. L. (2006). Paleozoology in the service of conservation biology. Evolutionary Anthropology: Issues, News, and Reviews: Issues, News, and Reviews, 15(1), 11-19.

Lyman, R. L. (2008). Quantitative paleozoology. Cambridge University Press.

MacArthur, R. H., & E. O. Wilson. 1967. The theory of Island biogeography. Princeton: Princeton University Press.

Martin, P. S. (1973). The Discovery of America: The first Americans may have swept the Western Hemisphere and decimated its fauna within 1000 years. Science, 179(4077), 969-974.

Martin, P. S., & Klein, R. G. (1984). Prehistoric overkill: the global model. Quaternary extinctions: a prehistoric revolution. University of Arizona Press. 354-403.

Martin, P. S. (2005). Twilight of the mammoths: Ice Age extinctions and the rewilding of America (Vol. 8). Univ of California Press.

Neef, E. (1967). Die theoretischen grundlagen landschaftslehre. Geographisch-Kartographische, Ansalt. Pages 18–38 in O. Bastian, The Theoretical Foundations of Landscape Study. VEB Hermann Harck, Gotha/Leipzig, Germany.

Redman, C. L. (1999). Human impact on ancient environments. University of Arizona Press.

Redman, C. L. (2005). Resilience theory in archaeology. American anthropologist, 107(1), 70-77.

Redman, C. (2012). Global environmental change, resilience, and sustainable outcomes. In Surviving Sudden Environmental Change: Answers from Archaeology (pp. 237-244). University Press of Colorado.

Redman, C. L., & Kinzig, A. P. (2003). Resilience of past landscapes: resilience theory, society, and the longue durée. Conservation ecology, 7(1).

Risser, P.G. (1987). Landscape Ecology: State of the Art. In: Turner, M.G. (eds) Landscape Heterogeneity and Disturbance. Ecological Studies, vol 64. Springer, New York, NY. https://doi.org/10.1007/978-1-4612-4742-5_1

Santana-Cordero A., Szabó, P., Bürgi, M. & Armstrong, C. (2024). The practice of historical ecology: What, when, where, how and what for in: AMBIO A Journal of the Human Environment. March 2024 https://link.springer.com/article/10.1007/s13280-024-01981-1

Sauer C. O. (1941) Foreword to Historical Geography, Annals of the Association of American Geographers, 31:1, 1-24, DOI: 10.1080/00045604109357211

Sauer, C. O. (1956). The education of a geographer. ANNALS of the Association of American Geographers, 46(3), 287-299.

Sauer, C. O. (1974). The fourth dimension of geography. ANNALS of the Association of American Geographers, 64(2), 189-192.

Szabó P. 2014 Historical ecology: past, present and future. Biol Rev Camb Philos Soc. 2015 Nov;90(4):997-1014. doi: 10.1111/brv.12141. Epub 2014 Aug 30. PMID: 25174685; PMCID: PMC54240

Troll, C. (1950). Die geographische Landschaft und ihre Erforschung (pp. 163-181). Springer Berlin Heidelberg.

Troll, C. (1960). The relationship between the climates, ecology and plant geography of the southern cold temperate zone and of the tropical high mountains. Proceedings of the Royal Society of London. Series B. Biological Sciences, 152(949), 529-532.

Troll, C. (1968). Geo-ecology of the mountainous regions of the tropical Americas. Geo-ecology of the mountainous regions of the tropical Americas.

Troll, C., van Eimern, J., & Daume, W. (1950). Herman Sörgels „Atlantropa“ In Geographischer Sicht. Erdkunde, 4(3/4), 177-188.

Tuttle, R. L. H. (1975) Paleoanthropology: Morphology and Paleoecology. Mouton Publishers, The Hague.

Van der Leeuw, S., & Redman, C. L. (2002). Placing archaeology at the center of socio-natural studies. American antiquity, 67(4), 597-605.

Wu, J., & Qi, Y. (2000). Dealing with scale in landscape analysis: an overview. Geographic Information Sciences, 6(1), 1-5.

SECTION 2

KEY SOURCES OF INFORMATION

This section presents five of the most commonly used types and sources of information that are used in Historical Ecology research. We begin with the most fundamental source of information, historical documents and records. These are the basis of most historical work, and are the primary documentation for political, economic, social, and other types of historical analysis. Such documents include everything from tax records to personal diaries, births and death records, old newspapers to map Atlases and more. Second, we look at the ecology side of Historical Ecology, with a consideration of the important topic of biological cultural heritage. Next, we explore paleoecology and its important contributions to our field, and this is followed by Toponymy, or the study of place names and how this can inform our analysis. Finally, we consider the use of historical cartography, a rich source of information for our research. Individually and together, these provide an important basis for our interdisciplinary endeavors. Together, these form several of the foundations of integrated Historical Ecology research.

CHAPTER 2

HISTORICAL DOCUMENTS AND RECORDS

ANNA WESTIN, SCOTT MADRY, AND ELIZABETH JONES

This chapter introduces the use of historical documents as sources in Historical Ecology research. There is a large range of purposes and contents of historical documents, and many of them hold important information about the use, qualities, agreements, and beliefs related to past ecosystems. Written words from the hands of people in the past, illustrations, and photographs are a direct link to these people's lives and conditions. Historical documents therefore play a vital role in Historical Ecology research. In this chapter we present several categories of historical documents and issues relating to their use. We provide an outline of the process of historical criticism that includes both external and internal analysis. The chapter will also describe a sampling of the kinds of historical documents that contain information relevant to Historical Ecology questions, including tax records, parish records, ethnological data, Atlases, photographs, and family records. Finally, the chapter describes several brief case studies from Sweden and France on how historical documents have contributed to historical ecological research questions.

Introduction

In pre-industrial societies, the majority of people were directly dependent on local natural resources for their daily needs. Before industrialization, the economy of western states rested mainly on food and fiber grown and harvested from local and regional ecosystems and used locally. There were also many reasons for writing down, drawing maps, or in other ways documenting conditions and agreements regarding people's use of ecosystems. Documents from such circumstances are therefore rich sources of knowledge for all kinds of Historical Ecology questions. Writing has a relatively short history in relation to the history of humanity and was preceded by oral communication and agreements. Even though oral communication has continued being of great importance, the written word made it possible to consolidate laws, agreements, assets, ownership and other important information in documents that could be communicated unchanged into other contexts in time and place. Written documents have preserved details of past societies' relationships with their environments in public archives and private holdings from past times that otherwise would have become lost and forgotten. With the right tools and knowledge, these documents are a gold mine for historical ecologists and others.

Historical Ecology brings together researchers from the natural sciences, social sciences, and the humanities. Researchers in the natural sciences are sometimes skeptical of the validity of information from historical documentary sources. They see that type of information as subjective and unreliable, especially when compared with the scientific method applied to the "hard sciences." Those not trained in the field of history often do not realize that trained historians apply a rigorous process of criticism to historical documentary data that includes both external and internal analysis. The uncritical and inexpert use of historical documents by researchers in fields outside of history who seek to use historical information to provide context to their own data, has led to the misuse and mistrust of historical information.

The oldest written documents were made by and for the educated elite, such as the royalty, nobility and clergy, and they were almost exclusively written and used by men. Laws, court records, tax registers, land purchases, cadastral maps, probate inventories and church records are examples of sources written by the elite that can be found in national, regional and local archives. With time, common people got access to basic education and could start writing and producing, for example, diaries, letters, private agreements, biographies, and farm records. These “ego-documents”, written by someone with inside knowledge, may have been collected by archives at a later stage, but are more likely kept privately by descendants of the authors, if they still exist. It is important to keep in mind that the survival of historical documents of any kind is haphazard. Even for government documents, fires, wars, and changing ideas about the value of documents affects what survives and what does not. In the early 20th century, as ethnologists noticed that folk culture had changed radically with the extensive effects of industrialization, ethnological archives started to collect knowledge and folklore of common people. It was at this time that a great deal of previously oral culture and knowledge was recorded for the first time.

Disciplinary underpinnings and perspectives

In their wider sense, historical documents include carvings on stone and wood, hammered coins and engraved medals. Interpretation of these belong mainly to the disciplines of archaeology, linguistics, and numismatics. The focus of this chapter, documentary sources replicated on paper or similar media, have traditionally been used in various historical disciplines such as political history, economic history, mentality history, social history, agrarian history and local history. Historical documents are a rich source to many historical ecological questions, especially in combination with other types of sources presented in this volume. Historical scholars have a long tradition of working alone in the archives, digging deep into their questions and publishing alone. The lone researcher has been the standard model in history research and monographs have been rewarded with greater scientific credit than co-authored publications. Authors in co-published books usually have individually written chapters and the different researchers rarely discuss each other’s work even when the book has a joint theme. When integrating historical documents in Historical Ecological projects, it is preferable, often even necessary, to cooperate with other scholars throughout the project, starting with formulating questions, continuing with discussing interpretations, exploring each other’s data and methods and writing chapters or papers together. This is a significant change in the way that many history researchers are used to working, however we acknowledge that cooperation is an increasing trend in historical research.

The use of historical data and analysis

Historical documents are often readily available from local, national, and international archives. Many such documents are now also available digitally and many archives can be searched online. Sometimes personal documents like diaries are found in the possession of family members or local historical associations.

Source criticism

Historical documents must be critically evaluated through a process called source criticism. This basic aspect of historical research is necessary because no documentation contains a complete and unbiased presentation of the subject matter. Today, people are becoming more and more aware of the need to be critically aware before using information from the flood of information we face every day, in order to differentiate between facts, fake-news and twisted interpretations by vested political and economic interests. This includes evaluating information in the media based on what we know about the current societal context, which groups in society that stand for impartial information, and which groups have a particular interest in the message coming through to the audience. Similarly, historical documents must be critically evaluated before they are used as sources.

Source criticism includes a critical examination of the used sources and an assessment of the credibility of statements made in any source of information. Historical documents were not created to answer the questions we want to address in our research. They originate from a specific historical context, created with methods and aims relevant to their time, which often poorly match what we find as relevant and interesting today. In using historical documents it is therefore important to understand what they can inform us about, and which questions that are difficult or even impossible to answer from these sources. In short, the source critical evaluation determines if, and how, a particular source can be used.

The process of historical criticism includes both external and internal analysis (Barber and Berdan 1998, Kyvig and Marty 2000).

- External analysis is designed to determine the authenticity and the context of the document. In other words, it examines if the source is what it claims to be. External analysis includes questions as:
- Can the historical continuity for the document be traced (i.e. chain of evidence)?
- Are the physical aspects of the document appropriate (i.e. the date of paper, pen, ink, pencil)?
- Is the handwriting appropriate in terms of date, style and characteristics fitting for the purported author?
- Are there anachronisms in words, phrases, spellings, polite usages, structures, or concepts? (anticipatory and retrospective).
- Is the document adequately consistent with the corpus of well-established sources?
- Internal analysis is designed to determine the credibility of the information contained within the document and includes such questions as:
- Was the author in a physical position (i.e. place and time) to report events or conditions?
- How much time elapsed between the events and the writing of the account?
- Did the author have the cultural background, including language proficiency, to understand what was observed?
- What were the author's biases, and how might they have affected their reporting?
- What were the author's vested interests, and how might it have affected their reporting?
- What elements are formulaic or expected within this genre, and which are unique and potentially meaningful?
- Was the report inherently plausible?
- How well does the report fit in with other evidence on the same issue?
- External analysis is of particular importance when working with private documents and local archives (or any source which so far has not been viewed with critical eyes). Internal analysis should always be applied. If you are working with a commonly used source, others may have evaluated its usefulness, but not always in ways that are relevant for your specific questions.

Source pluralism

In many Historical Ecological questions it is necessary to combine several different sources. These may give complementary information about the research question, complementing each other on types of information, temporal and spatial cover, and level of detail. For example, cadastral maps will show the location and size of pastures and may even provide information about productivity and vegetation. More detailed sources such as diaries may show how grazing was organized in time and space, and why they were organized in this way. If the map and the diary both refer to the same village, the grazing organization can be reconstructed (example 1.). Under beneficial conditions, field surveys of the pastures may add knowledge about productivity and tree cover. Together, these three sources give more information about the pasture than any of them could do alone, thus filling each other's information gaps.

If several sources provide similar information about something, they give support for a clearer interpretation. But it is also valuable when sources diverge because that highlights the need to reconsider the interpretations. Questions may need to be rephrased, sources may need to be re-evaluated, and involvement of further sources may be necessary, which develops new knowledge. Many Historical Ecological questions benefit from combining different documentary sources with non-documentary sources, such as ecology, oral information and archaeology. In addition, some data such as tax and land use information can be integrated into GIS for spatial and temporal analysis (see Chapter 11).

Spatial, institutional, and temporal scales

Historical documents may cover different scales, from individual statements in diaries, letters, court registers (micro scale), descriptions and statistics covering local-regional conditions (meso scale), up to national sources (macro scale). The micro scale often contains details that are missing from the other levels of information, for example, how people decided how to work their land depending on social relations, economy, technique and individual knowledge. On the one hand, information from individual persons cannot be seen as representative for a larger group of individuals. On the other hand, societies consist of individuals and such details shed light on what circumstances and motivations may be hidden behind official records at meso and macro-levels. They may illustrate how known societal or land use changes, known from the macro-level, were taking place in individual farms or households. The possibility to zoom in and zoom out in scale is always rewarding as it sheds light on both the overall picture and the details.

Example 1. Grazing according to an ethnological questionnaire and cadastral map

In 1941, Edith Östergran answered a questionnaire from the museum of Nordic cultural history (Nordiska museet) about livestock management (NM60 Boskapsskötsel). Edith was born in 1895 and retold information she received from her father about her childhood farm around 1870. At this time her father worked ⅛ of the village Österskog situated in the county of Jönköping, Sweden. Edith informs us that in 1879 there were two large oxen, four cows, two heifers, one calf, eight sheep, two sows, and five hens at the farm. She described six different pastures of varying productivity. Lassabohagen was the most productive. Kärrahagen, Nyröslet and Långelyckan were other productive pastures. Västbohagen was situated further from the others and Storåkersmaden was the least productive of the pastures because the soil consisted of peat. Also hay meadows and arable land served as pasture in late summer when vegetation had grown back after harvest. Every described pasture, and a few more, can be identified in the cadastral map over the village from 1882, made because of the land reform "laga skifte" (Figure 2.1). In laga skifte land was redistributed and common land (in particular pastures) became private.

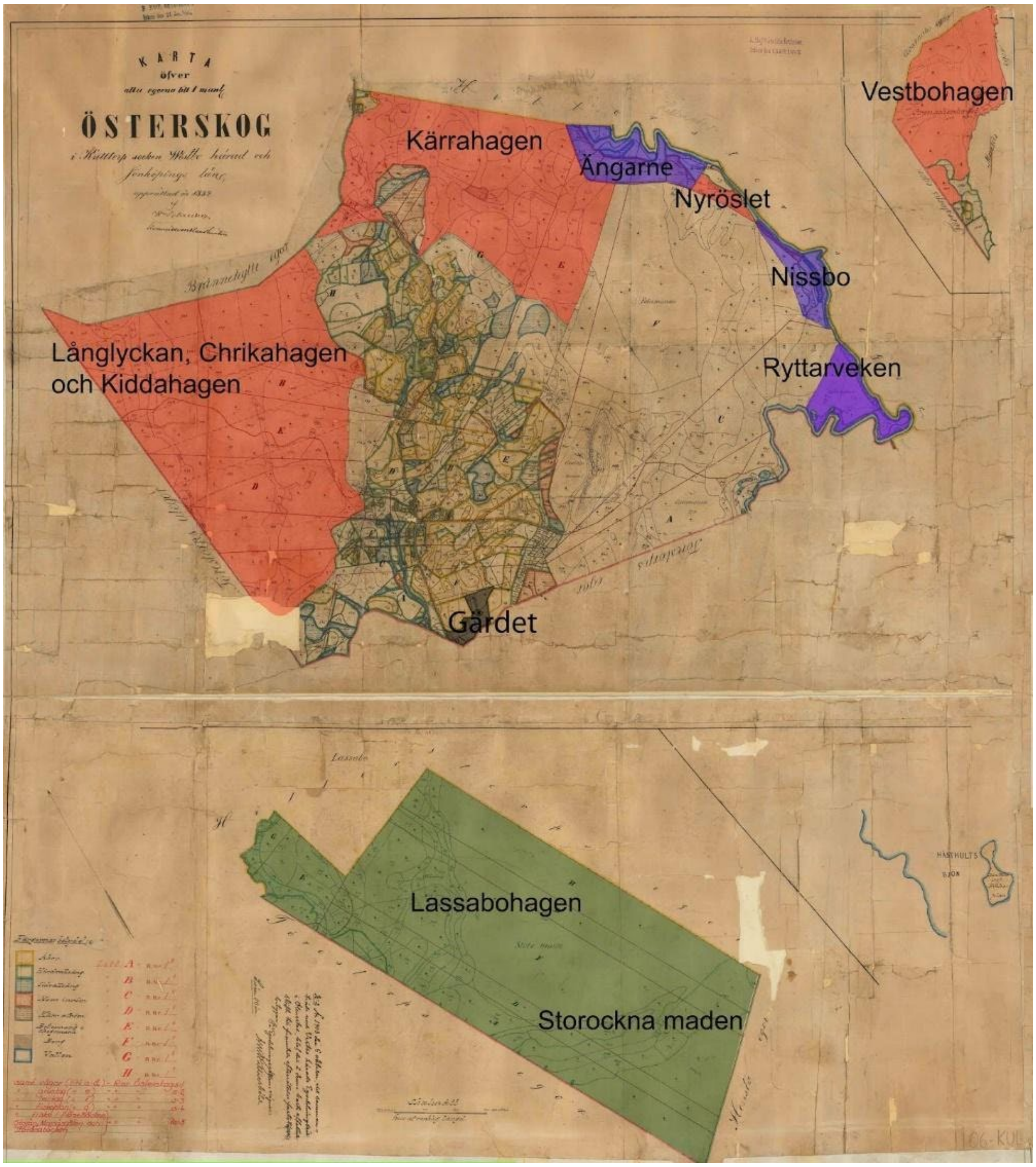


Figure 2.1. Cadastral map of Österskog from 1882, where the names and locations of pastures described by Edith Östergran have been highlighted. Source Lantmäterimyndigheternas arkiv 06-KUL-54.

Before 1882, pastures were commonly held and grazing was strictly regulated for all villagers, which was also described by Edith. The dates when livestock were moved was very exact in Österskog and she used entries from the calendar of 1870 as an example.

The combination of Edith's statement and the information in the cadastral map enabled a reconstruction of the grazing organization in this village before the land use reform (Figure 2.2). Furthermore, Ediths written statement explains how grazing organization reflected land productivity and cattle productivity. The best pasture, Lassabohagen, was reserved for high lactating cows, who had their calves late in winter. They were kept indoors, eating hay until early or mid-June when the vegetation in pasture had become lush. They also grazed hay meadows in late summer. Low-lactating cows were moved seven times between four intermediately productive pastures during the summer. Non-lactating cows and heifers were let out to graze in mid-May, and they had to settle for the least productive pasture, Storåkersmaden.

In addition to how grazing organization was influenced by productivity, we also expect different ecological responses in the vegetation from periodic and continuous grazing, for example in response to grazing pressure. Although we cannot measure grazing pressure in hindsight, we find it likely that grazing pressure was higher in the four pastures grazed by the migrating cows than in the continuously grazed pastures. In pastures with high grazing pressure, where nearly all vegetation, including flowers is being consumed, species that depend on yearly flowering and maturing seeds are disfavoured. Thus, we expect different grazing organizations to have shaped the vegetation composition differently.

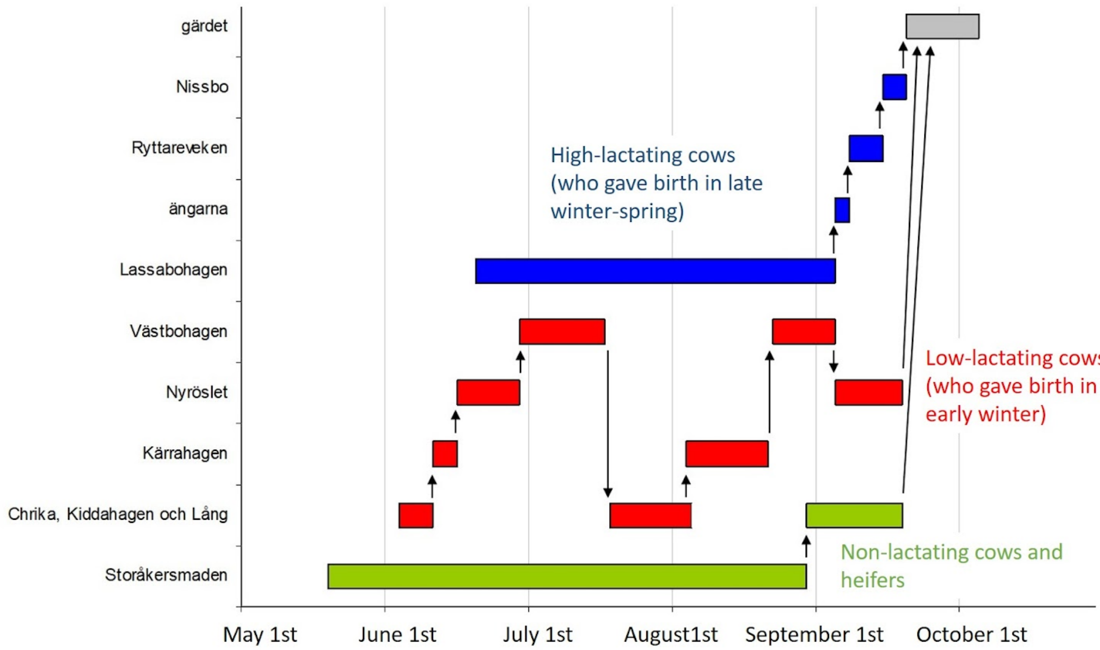


Figure 2.2. Grazing organization at Österskog village in the 1870'ies as described by Edith Östergran (see text). The information presented in example 1 shows how grazing was organized in one village in Sweden and it may be unique or representative for the region. It illustrates how grazing could be organized and how it related to cattle production and land productivity, without saying that other villages used the same organization. Despite being local, it holds invaluable information of a kind that is rare in historical sources.

Sources also differ in their temporal extent, from momentary (one day) to long time-series. Sources can be retrospective (reflecting on the past) or only inform us about the time they deal with. It is important to be aware of any particular circumstances (war, crop failure, livestock disease, economic crisis, exceptional prices etc.) before using momentary information as representative for a longer time period. Again, example 1 only shows data from one single year, but it most likely represents a somewhat longer time period, since the informant chose this year to illustrate grazing organization at her family farm. Retrospective sources may also be influenced by whether or not the source wants to highlight the past as being better or worse than the present.

Methods of collection and data analysis

The methods of data collection vary depending on sources and what kind of data that is used. There are two main lines of analysis of historical documents: quantitative and qualitative.

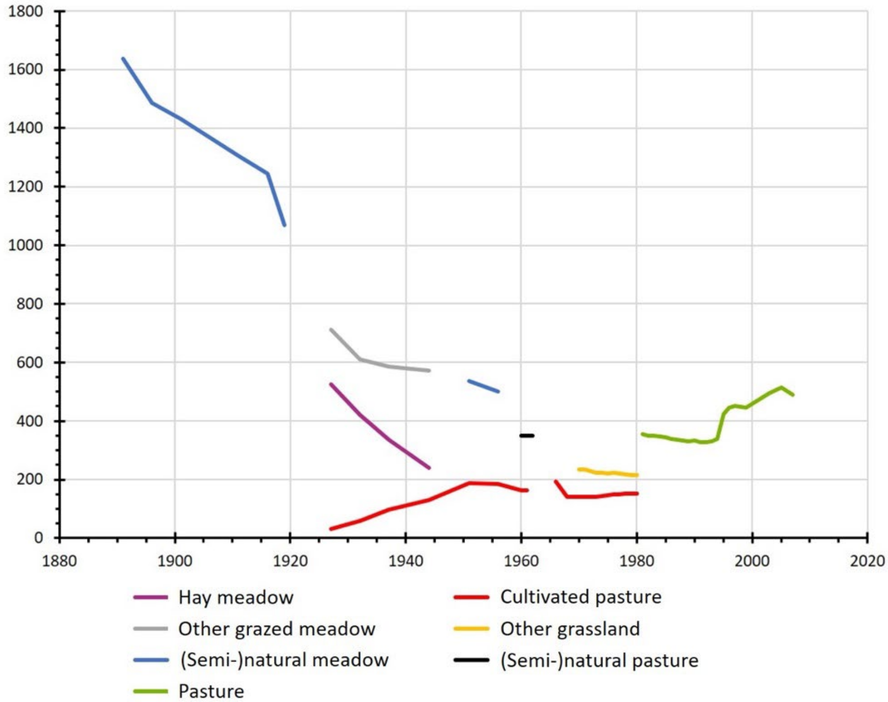


Figure 2.3. The area of different grassland categories in Sweden. The Y-axis shows thousands of hectares. Source: Jordbruksverket och Statistiska centralbyrån 2011, Figur 1L.

Quantitative analyses

Quantitative analysis aims to present numerical information, statistical surveys or present results in ways that can be generalized or compared. Some documents provide direct numerical data such as the number of inhabitants, cereal harvest, livestock numbers etc. These can be combined at some geographical level into time series, or used to compare conditions in different regions. Question could be, for example: Did the population increase as hay meadows were transformed into arable land during the 19th century? Does the number of cows per household correlate with the area of pasture during the early 19th century in Sweden?

Diagrams based on quantitative data have great benefits in being visually illustrative. It is easy for the plain eye to see how curves on diagrams vary over a timeline and it gives an immediate understanding on how things have changed. However, not everything that can be counted should be quantified, and it is important to ask oneself when quantifying is the best way to interpret pieces of information. Statistical results and diagrams will never be better than the input data and should always be combined with a source critical perspective. Before temporal comparisons can be made, research must be done into the methods of historical data collection. It is common that data from different times have different origins, which blurs the results. In Sweden for example, the first agricultural statistical data was collected around 1800 by the parish priests (Gadd & Jorner 1999). Since priests also collected tax from farmers, there was an incentive by farmers to keep harvest figures and other information low. During the rest of the 19th century, the data collection went from the church to the county administration, and later to regional farming associations, all using different methods. By 1913, Statistics Sweden started collecting more reliable statistical information, but the categorisations of land use types shifted with time. This makes it difficult to compare information over time. In diagrams, representing data of differing qualities, can be represented with different colors (Figure 2.3).

Data may sometimes be limited, but even with scarce or less stable data, quantitative analyses are valuable for finding patterns in the data, e.g. through plotting diagrams and tables, from which the results can be discussed. Large data sets are useful for making statistical analysis and finding large scale patterns that cannot be secured in small data sets. The data can be worked in Excel, minitab, R, or other statistical software commonly available. For large collections of qualitative data, analyses can be facilitated by the use of software such as nVivo and Atlas.ti. These programs can be used to sort, organize and perform quantitative analyses of qualitative information.

Figure 2.4. Cadastral map from 1642, the farm Bränntorp in the county of Östergötland in Sweden. The map shows the farmhouse, arable land (rectangles) surrounded by infield pasture, and to the left, a dry meadow with trees. The area outside the infield also belonged to the Bränntorp and was described as “forest and pasture sufficient”. Source: Lantmäteristyrelsens arkiv D51-12:D8:64.

Qualitative analysis

Qualitative analysis is a group of scientific methods used to collect and interpret text or other non-numerical data. The methods of hermeneutics is all about how to understand text, including from historical documents. Interpretation is a part of all historical data and is especially important using qualitative data. Interpretation differentiates between the data and how the author understands the data in relation to the posed questions. It usually includes posing a larger question or research domain which is divided into smaller questions. These are answered, going through information from one or several sources and presented in text. The reader is thereby guided through the question, choice of source, the data, and its interpretation. The researcher must be clear on the data input, interpretation process, and its results. In this way, others can read the text and agree on the interpretation or come to different conclusions. The questions may be more explorative such as: "how did the agrarian revolution affect landless people in the mining district of Sweden, with regard to wealth?", or more normative, such as "did landless people get poorer during the during the agrarian revolution in the mining district of Sweden?". The answer to normative questions is rarely a simple yes or no, but rather what information supports "yes", and what supports "no". Perhaps some landless people in the mining district became poorer but not all. In this case, a deeper discussion around the definition of "poverty" may be required. The discussion itself will reveal much new information about the situation for the landless groups, and leads to new insights about what changed in the society regarding this group of people. Of course, qualitative analyses may also give clear patterns, such as the ecotypes of families in Burgundy in the 1690s (see example 3).

Qualitative sources can sometimes also be quantified, for example, comparing the written statements of forest quality in cadastral maps such as in figure 2.4 . In one study we compared how the forest was described in 150 cadastral maps from the 17th century, situated in four different Swedish regions. The result (Figure 2.5), shows regional differences between maps, which must be interpreted before concluding if they also reflect differences in forest quality. For example, slash and burn cultivation were mentioned only in the maps of Alseda. Perhaps slash and burn cultivation was particular for Alseda and did not occur in the other regions. But an alternative explanation is that only the surveyor working in Alseda took notice of this forest use, while other surveyors did not. The forest was not of primary interest in these maps, and different surveyors could have put different efforts into the forest descriptions. Also GIS is useful to analyse and illustrate qualitative information (Figure 2.7, 2.21, 2.22, see also Chapter 11).

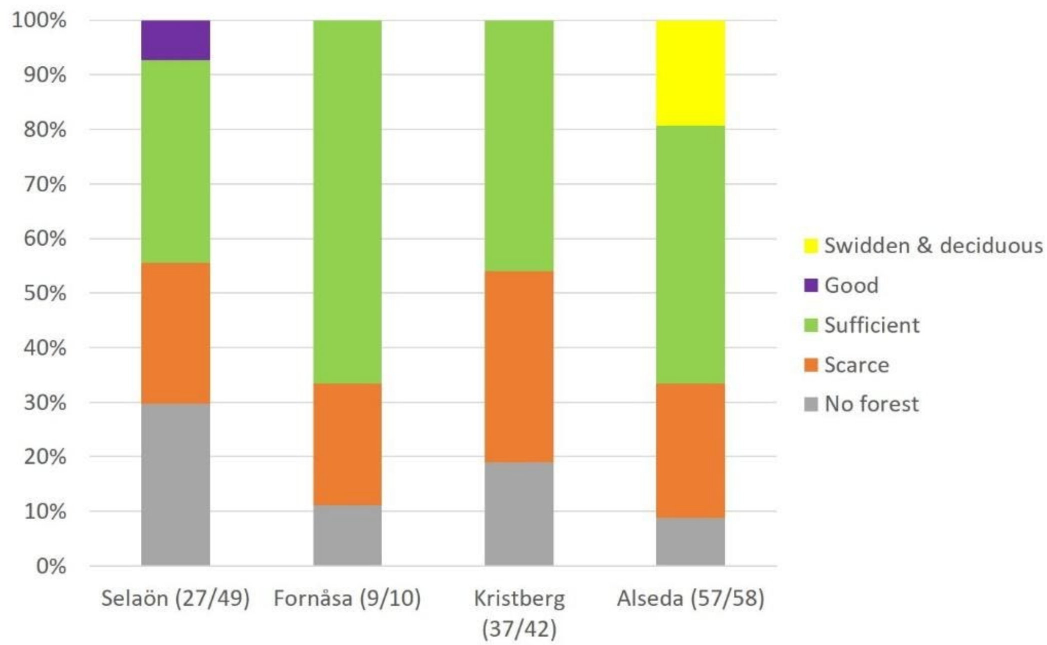


Figure 2.5. The forest quality described in cadastral maps from different regions in south-central Sweden: Selaön and Fornåsa are situated in the plains, Kristberg and Alseda in hilly forested areas. The graph shows the proportion of villages where the forest was described as good, sufficient, scarce or no forest in cadastral maps from the early 17th century. Swidden and deciduous forest was only described from one parish. Within brackets are the number of analyzed villages where there was a description vs, the total number of analyzed cadastral maps. Data from Dahlström 2006.

A selection of documentary sources

Societies have created documents throughout history, resulting from different institutional and private affairs such as royal, political, ecclesiastical, legal and statistical activities, documenting agreements, private correspondence and diaries, among many others. The kinds of available documents differ between countries, regions and time periods. Here, we present the primary sources most commonly used in our own projects, along with examples. We also address source critical aspects, access and copyright issues.

Parish records

In Sweden and other countries, the church kept track of the members in the parish. The priest kept registers for people moving to and from his parish, deaths, births, christenings, God parents and marriages. Parish records in Sweden are available from late 17th century to early 19th century. They are generally very accurate sources and give detailed information about households and people. In Sweden, the priest performed yearly hearings to investigate people's biblical knowledge. At the hearings, all people living in each household (including maids and farm hands) give an overview of which persons were associated with different households. Swedish parish records have been scanned and are free to use via the National archive: https://sok.riksarkivet.se

These registers provide an important background image of the study area, who lived there, people's positions in the society, socio-economic patterns, social relations and migratory patterns. In the reading of diaries, letters and other documents, it is essential to have an idea of the social context. For example, in one of our Swedish study areas of southern Dalarna, several farmers kept diaries in the same time period. By comparing the information in the diaries, we could easily see that several of the authors of the diaries were close relatives and the relationship to different people mentioned in the diaries was clearer to us. This gives us a better understanding of how ideas could spread, who bought grains and cows from who and the place of origin of farm hands and maids, etc.

In France, Elizabeth Anne Jones has reconstructed family relationships and the land use patterns in Burgundy by using information from the parish record (see example 4).

Cadastral maps and other cadastral records

A cadastre is a recording of properties, land use and land ownership, usually defining the dimension and location of land described in legal documents. Cadastres are often maps documenting borders, ownership, land use and other information necessary to ensure land valuation and taxation. In Sweden, cadastral maps were first produced from the early 17th century, which is early in international comparison, and continues up to the present. The different generations of maps contain different kinds of information, depending on the methods used and the aims of the map. Cadastral maps are very useful in Historical Ecology research. Primarily, we use the size and location of different land use types such as garden, arable land, hay meadows, pasture and forest in order to reconstruct land use history. Secondly, it is interesting to read how different parcels have been described in terms of vegetation and productivity, since they give important information about ecosystems. Thirdly, the location of fences is used to understand past grazing organization, i.e. timing of grazing in different kinds of pastures (Figure 2.6), which also may have shaped vegetation in ways that can be traced for centuries (see chapter 2 biological cultural heritage and Example 1).

These cadastral maps are impressively correct, given the cartographic methods used in these early times (see chapter 6 Historical Cartography). Information about ecosystems must be interpreted before it is used. For example, the maps usually only note some tree species in the forest, and the forest quality was expressed in terms relevant for people's use of forest, i.e. sufficiency of timber, fencing and firewood, or economic value. Fences are not depicted in all maps, especially not small-scale maps.

Cadastral maps largely have been scanned in Sweden and are free to use at: https://www.lantmateriet.se/historiskakartor. Romanian cadastral maps made by the Austro-Hungarian empire in the late 19th century are published at https://maps.arcanum.com/en/map/cadastral/. Also, see chapter 6 Historical Cartography for French maps.

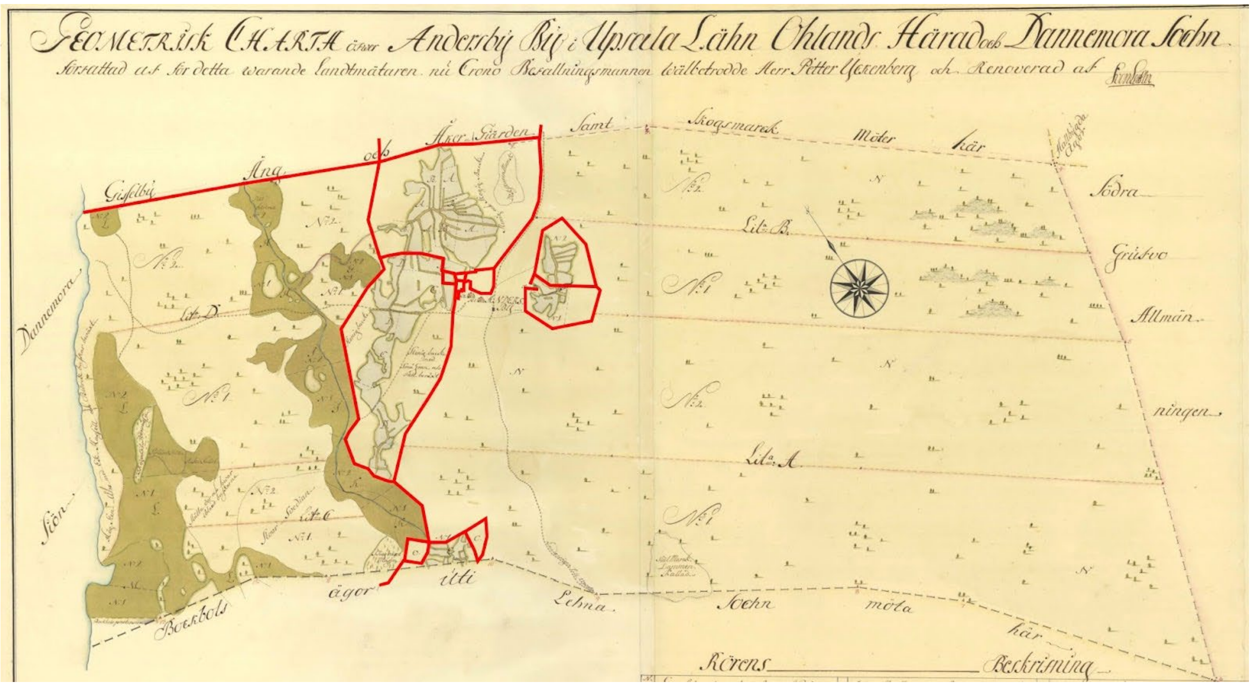


Figure 2.6. Cadastral map of the village Andersby, from 1739. Infields are situated to the left with arable land and hay meadows. The fencing system (red lines) reveals how grazing was organized in the village. Outland pastures to the east could be grazed all summer, and pastures situated in the west could be grazed only after the harvest on arable land and hay meadows, i.e. late August or September.

Tax records

Property and personal belongings subject to taxation have been recorded by the state for a very long time. Land, harvest, livestock, charcoal, and other items can therefore be found in registers at household, farm, or village level. These are all keys to understand subsistence, land use, and other information relevant to Historical Ecology. The subjects of taxation and the position of the tax collector differ between areas and time periods. There is reason to suspect that people were hesitant to give correct information to tax collectors, and that tax records therefore may underestimate what people owned and harvested.

In Sweden there was an extra tax on livestock and arable land during 1620-1641 as a means to finance participation in the 30-year war. Each household paid tax per livestock over one year of age with different rates for different species and ages. Each winter, royal representatives counted livestock and made registers, bringing us a unique opportunity to know how much livestock individual farms had, how livestock composition differed between farmers in different regions (Figure 2.7), and how livestock varied between years. From 1642 the direct tax was replaced by a fixed sum and no more registers were made. The next time in history when livestock were regularly registered in Sweden is in the mid 1800´s when probate inventories became common.

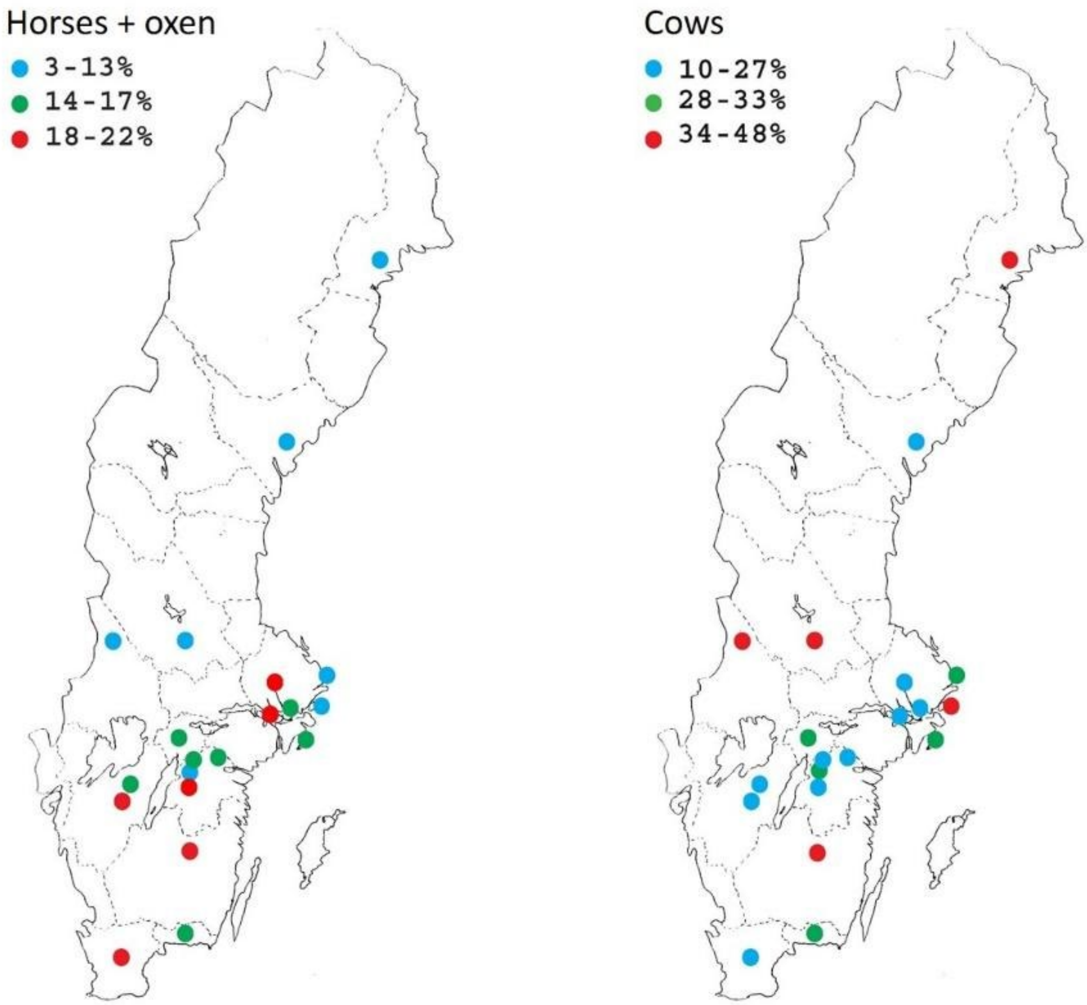


Figure 2.7. Livestock composition in the early 17th century based on studies using livestock tax registers. Not surprisingly, there was a larger proportion of working animals in regions in the plains where work in the fields was important or oxen were brought up (left map). Forested regions, where the economy was more based on milk production instead had more cows (right map). Illustration and references from Dahlström 2006.

Probate inventories

Probate inventories are important sources showing all property belonging to a deceased person at the time of death. Reading these inventories is almost like walking into the house of the deceased, as basically everything of economic value was listed: land, livestock, farm tools, wagons, kitchen equipment, looms, clothes and much more. These lists give invaluable insights into the farmers' lives and how they worked the land. Livestock is of particular interest (Figure 2.8), since information about animal husbandry and grazing is sparse in most historical sources.

Giving correct information was in the interest of everyone involved. However, assets of little economic value, and livestock reserved for the funeral may be missing, as well as food which usually was taken care of by relatives before the inventory was made. If people died old, it is likely that most belongings were already given to children. Therefore, the tragic cases, such as when people died in active ages, leaving young children and spouses behind, are most informative about the active farming. The inventories also declare the heirs of the deceased and therefore complement parish records with information about relatives.

Table 2.1. The Othemars farm in the county of Gotland in Sweden, was divided into smaller farming units during the course of the 18th and 19th centuries. Useful probate inventories (i.e. from active farmers/wives) have been color-marked. From Westin & Lennartsson 2017.

<table>
<tr><td>Decade</td><td colspan="9">Othemars parts of 1 farming unit (Sw. hemman)</td></tr>
<tr><td>1654</td><td colspan="9">Gudmund Jönsson</td></tr>
<tr><td>1700</td><td colspan="4">Lars</td><td colspan="5">Jöns</td></tr>
<tr><td>1710</td><td colspan="4">Lars</td><td colspan="5">Jöns</td></tr>
<tr><td>1720</td><td colspan="4">Lars</td><td colspan="5">Jöns</td></tr>
<tr><td>1730</td><td colspan="4">Lars</td><td colspan="5">Jöns</td></tr>
<tr><td>1740</td><td>¼</td><td colspan="3">¼</td><td colspan="5">½</td></tr>
<tr><td>1750</td><td>¼</td><td colspan="3">¼</td><td colspan="2">¼</td><td colspan="3">¼</td></tr>
<tr><td>1760</td><td>¼</td><td colspan="3">¼</td><td colspan="2">¼</td><td colspan="3">¼</td></tr>
<tr><td>1770</td><td>¼</td><td colspan="3">¼</td><td colspan="2">¼</td><td colspan="3">¼</td></tr>
<tr><td>1780</td><td>¼</td><td colspan="3">¼</td><td colspan="2">¼</td><td colspan="3">¼</td></tr>
<tr><td>1790</td><td>¼</td><td colspan="3">¼</td><td colspan="2">¼</td><td colspan="3">¼</td></tr>
<tr><td>1800</td><td>¼</td><td colspan="3">¼</td><td colspan="2">¼</td><td colspan="3">¼</td></tr>
<tr><td>1810</td><td>¼</td><td>1/8</td><td colspan="2">1/8</td><td colspan="2">¼</td><td colspan="3">¼</td></tr>
<tr><td>1820</td><td>¼</td><td>1/8</td><td>1/16</td><td>1/16</td><td>1/8</td><td>1/8</td><td colspan="2">1/8</td><td>1/8</td></tr>
<tr><td>1830</td><td>¼</td><td>1/8</td><td>1/16</td><td>1/16</td><td>1/8</td><td>1/8</td><td>1/16</td><td colspan="2">3/16</td></tr>
<tr><td>1840</td><td>¼</td><td>1/8</td><td>1/16</td><td>1/16</td><td colspan="2">¼</td><td>1/16</td><td colspan="2">3/16</td></tr>
<tr><td>1850</td><td>¼</td><td>1/8</td><td>1/16</td><td>1/16</td><td colspan="2">¼</td><td>1/16</td><td colspan="2">3/16</td></tr>
<tr><td>1860</td><td>¼</td><td>1/8</td><td>1/16</td><td>1/16</td><td colspan="2">¼</td><td>1/16</td><td colspan="2">3/16</td></tr>
</table>

In Sweden, probate inventories became mandatory for all deceased persons from 1750. They are kept at National and regional Archives and many of them are digitally available. The strength of probate inventories is that they are very detailed about each separate case. On the other side is that the cases are irregular in time and space, i.e. the deaths of people were usually random. It may therefore be challenging if the study unit is the village and not the individual. We have used probate inventories to reconstruct livestock numbers at the village level. It is important to keep in mind that the property of the deceased only represents one part of all the potential livestock owners in the village. Therefore, it is important to know which part each probate inventory constitutes. Here, other sources, such as parish records, tax records and cadastres are useful. In Table 2.1, we have mapped one village, Othemars, in the county of Gotland, Sweden. The village was originally one single farm, but during the 18th and 19th century it was divided into smaller farming units. The reconstruction of livestock numbers must take use of this information to be as correct as possible. In addition to the farming households, old parents, unmarried adult children, and landless in the village could own some livestock.

In Table 2.2 the information from probate inventories indicated in Table 2.1 have been combined and the total number of horses, cattle, sheep and goats calculated. Combined with the area of pasture from cadastral maps from different times, we calculate the stocking density. During these two centuries stocking density varied between 0.07 and 0.11 Grazing equivalents per hectare (equals 0.07-0.11 adult cattle per hectare). There was no trend of increasing grazing pressure, despite increased population and farming units, indicating that the pastures were fully utilized already in the early 18th century. The stocking density was low in comparison with that calculated in other regions, which is in concordance with the low productivity of this dry area.

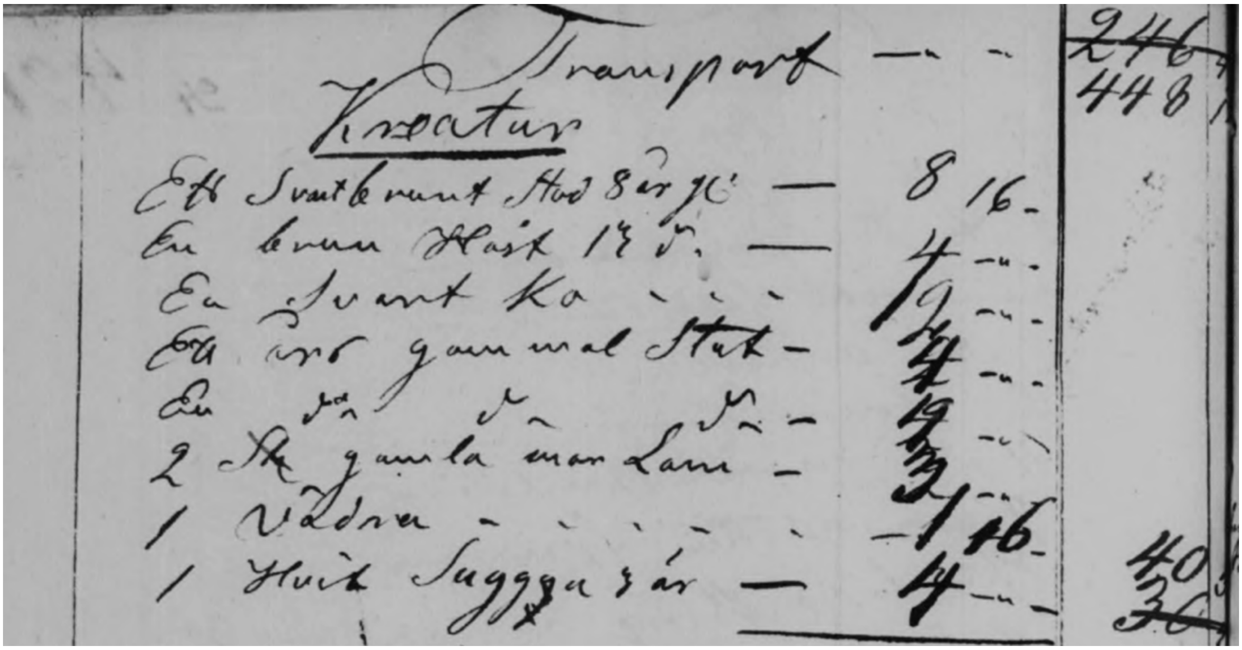


Figure 2.8. Livestock belonging to the farmer Lars Hansson, in the parish Othem on the island of Gotland at the time of his death in 1833: "One black-brown mare 8 years, one brown male horse 13 years, one black cow, one year old steer, one ditto, 2 old female sheep, 1 ram, 1 white sow". The total value was 40 Riksdaler.

Letters and diaries

Through letters and diaries, we have the possibility to come closer to the historical people than from any other historical sources (Lorenzen-Schmidt & Poulsen). Through them we can take part of people's daily lives, including work and struggles, joys and parties, relations, and private thoughts. Working with peasant diaries has enabled us to reconstruct land use in great detail, day by day, parcel by parcel, crops and workers, and how conditions changed over seasons and years. In some cases, the authors have also shared personal thoughts, troubles, aspirations and hopes, giving us direct insights into the inner lives of people (see example 2).

Table 2.2. Calculated livestock numbers in Othemars from probate inventories, excluding livestock belonging to landless people. Horses, cattle, sheep and goats have been combined into Grazing equivalents using their relative energy demand. From Westin & Lennartsson 2017.

Time period	Horses	Cattle	Sheep	Goats	G.equiv	Representation *
1: 1706-1726	24	40	34	9	86	100 %
2: 1773-1777	16	28	23	9	61	75 %
3: 1790-1804	13	20	31	0	49	75 %
4: 1813-1816	18	24	22	0	57	62,5 %
5: 1821-1833	16	36	52	0	75	50 %
6: 1856-1872	12	37	39	0	65	100 %

* The column shows the large proportion of the village that is represented by probate inventories from each time period. The higher the number, the better the accuracy.

None of these sources were invoked by authorities, which makes them different in terms of credibility and availability. Letters were written with the receiver in mind, and of course, this affected not only what was written, but also how. Diaries were usually kept for private use and probably reflect what was of personal interest and importance. There is no obvious bias in diaries, but they have a tendency to leave out information that was common knowledge for the author and the receiver, but which may be difficult to understand today. Most diaries were written by men and they always under-represent the daily tasks performed by women, such as tending livestock, milking, cooking, gardening and taking care of children and the elderly. The farmers of Hyttbäcken in south Dalarna, kept diaries over an 80-year period. Information about their economy and employment of several maids points to the importance of cows, milk and butter. Milking was a part of women's daily work but the only time it was mentioned in the diary was the day when the farmer himself had to do the milking because a maid was absent.

Letters and diaries are usually taken care of by descendants unless they were given to an archive. A collection of peasant diaries from different parts of Sweden have been collected and transcribed by the Nordic museum of cultural history (Nordiska museet), where anyone can read them. People who wrote diaries sometimes also kept their own farm records of harvests, the weather, and the economy.

Permission from descendants may be required before using private archives, unless they are owned by an archive. If the descendants and holders of the archive are interested in research on their family farm, they can also be of great help in learning to know the study area, local place names, people who used to live there and other things of interest (such as old farm tools, saved tools, etc. that add valuable information) See also chapters 5, 6, 8, and 9.

Ethnological data and local history literature

Ethnological institutions of many countries have long worked with collecting and presenting traditions, customs, other practices and language connected to folklore and traditional lifestyles (Poirier 1968). One common method was to distribute questionnaires to informants in the countryside regarding specific themes, among which some includes agriculture, livestock husbandry and forest use. The replies offer detailed and interesting descriptions useful to various Historical Ecological issues. Important source critical aspects regard aspects of memory, how people frame the traditional and the past, and how the questions of questionnaires have directed the informants to focus on what was considered of interest for the research department (Östling 2010).

For some regions, ethnological information has already been collected and published by researchers or interested amateur historians. Local history literature can be based on historical sources, ethnological data, oral history and personal memory and can give invaluable insights if they were made by persons with good local knowledge and source critical eyes. Example 1 Shows one use of an ethnological questionnaire from our work.

Historical Atlases

An Atlas is a particular type of document that contains a bound collection of maps as well as additional text, tables, graphs, and illustrations. Atlases have been popular since the great age of discovery in the 1500-1600's, and they can be global, national, or regional in coverage. The first modern Atlas was called Theatrum Orbis Terrarium (Theatre of the orb of the world), which was produced by the Dutch cartographer Abraham Ortelius in 1570. It was very popular and was produced for years in some 25 editions and in seven different languages. The name Atlas derives from the use by Gerhardus Mercator of an image of the titan Atlas from Greek mythology, supporting the globe in his first edition, and the use and name became generally accepted (Figure 2.9).

Figure 2.9. The use of Atlas supporting the globe in the title page for Mercator's Atlas Minor of Hondus (https://en.wikipedia.org/wiki/Gerardus_Mercator#/media/File:Mercator_Hondius_Atlas_Minor_of_1607_frontispiece.png)

Since then, global, national and regional atlases have been produced throughout Europe and North America, but less so in other regions around the world. While often the maps themselves are relatively general and less detailed, these Atlases can provide useful historical information about population demographics, agricultural production, economic and political factors and more, all of which can be useful information for Historical Ecology researchers. Many national and regional libraries contain copies of local atlases, and many of these are now being made available in digital format online. They are also available from private map stores and commercially online.

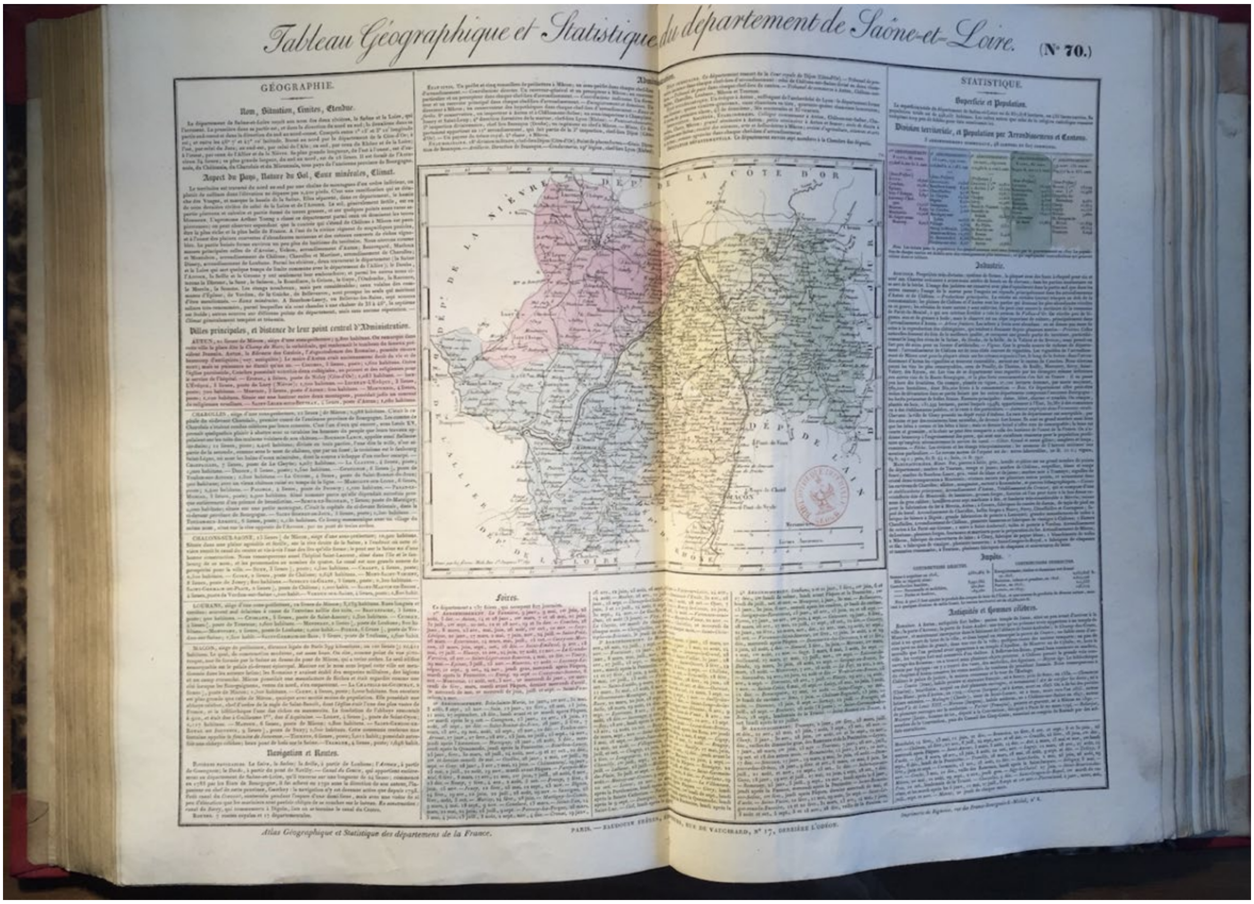


Figure 2.10. The Saone-et-Loire page of the 1832 Atlas, which includes our study area of Burgundy, France in the southwestern corner of the map. The map is surrounded by text data specific to this region. Image by S. Madry, document from the BNF, Paris.

The maps are useful, but it is the associated textual description of the department that is most interesting. The text from this Atlas includes information in the following categories:

Geography: name, location, boundaries, scope, aspect of the country, nature of the soil, mineral waters, climate, main cities, and distance from their central point of administration, administration, fairs.

Statistical: area and population, territorial division, and population by arrondissement and canton, industry, taxes, antiquities and famous people.

A few specific examples from our study area in Burgundy from 1832 (Figure 2.10) include the following. Vines were of great importance and "is the department's great source of wealth, the arrondissement of Chalons is covered on all sides with vineyards." and "The wines from this department are regarded by foreigners as inferior to other wines from La Haute Bourgogne, and the highest consumption is within France. It travels little outside the borders. There are, planted in vines, 27,700 hectares forming, per average year, 762,000 hectoliters, of which 562,000 pounds are for consumption." Also, fruit trees in the region were of importance and abundant, however "not enough care is given to the reproduction of chestnut trees, which have tended to decline for several years." Concerning forest, the Atlas described "beautiful high forest. Main species: oak, beech, hornbeam and aspen." A great deal of other anecdotal information is included, providing a rich context for our understanding of the people and their environment at that time.

Historical Atlases provide a variety of useful data for Historical Ecology researchers. The data contained vary widely, but their popularity provided a frequent regional accounting of geographic, social, economic, and demographic information that included interesting and unusual data not found in other sources. These regional data are very useful for placing into context the more detailed information provided by local population and tax records and cadastral maps for individual study project regions.

Figure 2.11. A picture postcard from around 1910 of Uxeau, France. A vineyard is at right. From the collection of the authors.

Picture postcards and private photographs

Picture postcards have been very popular in many countries from the 1880's through today and they can sometimes be used to create time series, as discussed in chapter 8. Pictures were taken from the ground or from air (Figure 2.11 and 2.12). There are thousands of old postcards available in archives, online, and for sale in local markets and through other sources. The study of historical postcards is called deltiology in English, and there are several publications regarding their use in historical and environmental time series (Debussche et al.1999, Paxion and Cohen 2002, Sawyer and Butler 2006). In French, those who collect these are referred to as 'cartofiles', and the collection of these is the third most popular collecting hobby in France, after the collection of coins and stamps. This popularity makes for a rich source of data for researchers.

Figure 2.12. An aerial view of Uxeau with Mont Dardon in the background. Taken around 1950. This oblique aerial photo shows the tiny village of Uxeau, in the heart of our study area. The church with its cemetery is central to the view, with the Iron Age hillfort of Mont Dardon in the background. Many details of field divisions, vegetation, land use, forest cover, and settlement can be extracted from this single image. (Image from Scott Madry's private collection).

In 1889, one picture postcard with the newly built Eiffel Tower in Paris sold over 300,000 copies and was instrumental in increasing the popularity of the idea. The golden age of this was between ~1900 and the end of the Great war when the popularity of these began to decline. Production continued, and color postcards were introduced in the late 1950's and early 1960's, and oblique aerial photos also became popular. In our study area in France there was a husband-and-wife team who owned a small airplane. They took aerial photos of local farms and villages and sold the aerial picture postcards throughout the region (Figure 2.12). There is even a French museum of the postcard, located in Baud in Brittany (Le Carton Voyageur - Musée de la carte postale, 3 Av. Jean Moulin, 56150 Baud, France).

From the early ages of photography, it was also common that ethnologists and enthusiasts started documenting the countryside in their profession or out of their own interest. Also, it became popular among wealthier private persons to have their pictures taken, often in front of their houses, business, or in their gardens. Other photos were taken in the rural landscapes around the houses or further out in the landscape. A Sweden example is the landscape researcher Mårten Sjöbeck who left a valuable treasure of publications and photos, documenting traditional landscapes, habitats, land uses methods, houses, roads, technique and people (Figure 2.13).

Figure 2.13. This picture from 1932 illustrates methods of leaf harvest and the tools used in the village Ödenäs in the county of Västra Götaland. Photo: Mårten Sjöbeck. RAÄ kulturmiljöbild, PDM.

Picture postcards and private photos can be excellent sources of information for example indicating vegetation cover, land use, buildings, bridges, tools, livestock and more. Photos have an authentic aspect in showing everything that is included in the picture in great detail. In this respect old photos don't lie. On the other hand, the motive was chosen, usually for a reason. Before using photos as sources, potential biases must be considered. Many private pictures were taken in front of houses, of people in their best clothes, possibly together with their best horse. At a special occasion like this, people probably put care in choosing what the picture should show the viewer. Early countryside photographers perhaps had a tendency to document the particularly beautiful spots, the novel, the traditional clothes, only wooden houses, or other special interests. Other areas were left unphotographed.

Dating images is a key aspect of their use. Photos with people can be dated using information about the identification and age of the individuals. Picture postcards can also be dated by:

- The general style of the postcard, full or half sized image, etc.
- The postage paid, stamp type, and canceling postmark
- The size of the postcard and if it is color or black and white
- How the card is addressed, address codes, etc.

- The quality and type of paper and printing used
- The printed legend and producer name and address
- Other identifying marks or codes from the publisher

If a card's exact date cannot be specifically identified, it can still be generally dated by the styles of clothes, vehicles, furniture, and other features. But it must be pointed out that there can be a significant and unknown delay between when a photograph was taken and when the postcard was produced, or when it was sent and postmarked, so there is always some ambiguity in the dating. The general history and means of dating French postcards is well described in the literature (https://www.abelard.org/france/dating_postcards.php) and for the U.S. see: https://www.fortlewis.edu/finding_aids/images/M194/PostcardDating.htm

The identification and dating of picture postcards is specific to each individual nation. Many regional archives collect and make available these historical items, and many are available for commercial sale on the internet and at markets. Historic picture postcards are readily available throughout much of the world. In Sweden, using digitized photos may be completely free of charge and free to use, but photos from some other archives are expensive to get access to, and you may not be able to publish them or require explicit permission to do so. Current photos from the same vantage point can be taken to measure changes (Figure 2.15 and 2.16).

Figure 2.14. A French owner of the former grist mill Moulin de Bauzot, with his poster of the historical postcard of his home. Photo taken by the authors in 2009 while conducting field surveys of mills and millponds in the area (Madry et al. 2015). We see these frequently in the region and this photo of the current landowner and his enlargement of his house illustrates the continuing interest of local people in their history and historical postcards.

Figure 2.15. Uxeau ground view in the 1940's. This view shows the area that is in the extreme bottom right corner of the aerial image (Figure 2.11). The new monument to the residents of the commune who died in the Great War is at left, confirming that the picture was taken after 1918.

Figure 2.16. A similar view from Google Street View showing Uxeau today. Image courtesy Google.

We have used the analysis of historical picture postcards in our French study area for many years and have amassed a sizable collection. We have used these to identify land use and vegetation cover and other features of the landscape.

Case Studies from our research projects and study areas

Example 2. The social-ecological safety net of a Swedish 19th century vicar

In September 1813, on his 50th birthday, the Swedish vicar and farmer Johan Fredrik Munchtell started writing a diary. In almost 1,500 pages Muncktell described, among other things, how an agrarian subsistence system worked, how it changed, and how it was perceived by a single household between 1814 and 1829. Through the information it contains, we can come close to understanding the decisions and actions taken by an actual land-user 200 years ago.

In this study, we focused on the management of hay and pastures through the analytical lens of a social-ecological system (SES) to analyze the qualitative data of the diary. SES is a framework that helps focus on how ecosystems and socio-economic factors interact in detail in historical or current societies (Lennartsson et al 2015).

From the diary, we identified four main domains in the SES of Muncktell: ecosystems (hay meadows and pastures), market (buying and selling), labor and technique, and social relations. Muncktell's detailed diary provides several examples of how different domains of the household's social-ecological arena interacted. The SES of Muncktell can be described as follows. The farm cultivated large amounts of the cash crop rye, which was motivated by the household's high costs for labor and consumption, the latter in turn largely necessary for the household's social status. The rye cultivation required many oxen and horses for traction power. Muncktell had as many as 12 oxen and 4 or 5 horses, with which he cultivated ~50 ha. of arable land per year. The animals required large quantities of hay and large areas of pasture, but the rye cultivation decreased the supply of hay since rye was favored on arable land at the expense of hay production. In all, the system had become vulnerable to years with low grass production.

We illustrate the SES further using an example starting from the harsh weather's effects on the supply of hay. Muncktell seems to have regularly suffered from a shortage of hay in the late winter, a problem that was particularly pronounced in years of drought (poor growth) or rain (difficult harvest). He combined different measures to solve the problem. One was to use arable land for hay production (1 in Figure 2.17), either by sowing clover or timothy or by allowing natural grass growth. This is a transformation of ecosystem resources, as illustrated by an arrow within the ecosystem domain. This measure reduced the area available for production of rye and thus the production of rye for sale (1a). Thus, the arrow indicates that the ecosystem measure had an effect on the market domain. Another possibility was to sell a horse in the autumn, and buy one back in the spring, however usually at a higher price (2). The most important measure was to borrow or buy hay from friends and neighbors within his social network (3). This created social debts (3a) and Muncktell was expected to give favors in return, for example by providing cheap (below market price) rye when requested (3b). When the hay prices were high and prices on cereals low, Muncktell chose to feed the animals with cereals (4), which reduced the amount he could sell (4b). Finally, Muncktell used the boys he was catechising as labor for collecting leaf fodder to supplement the hay (5).

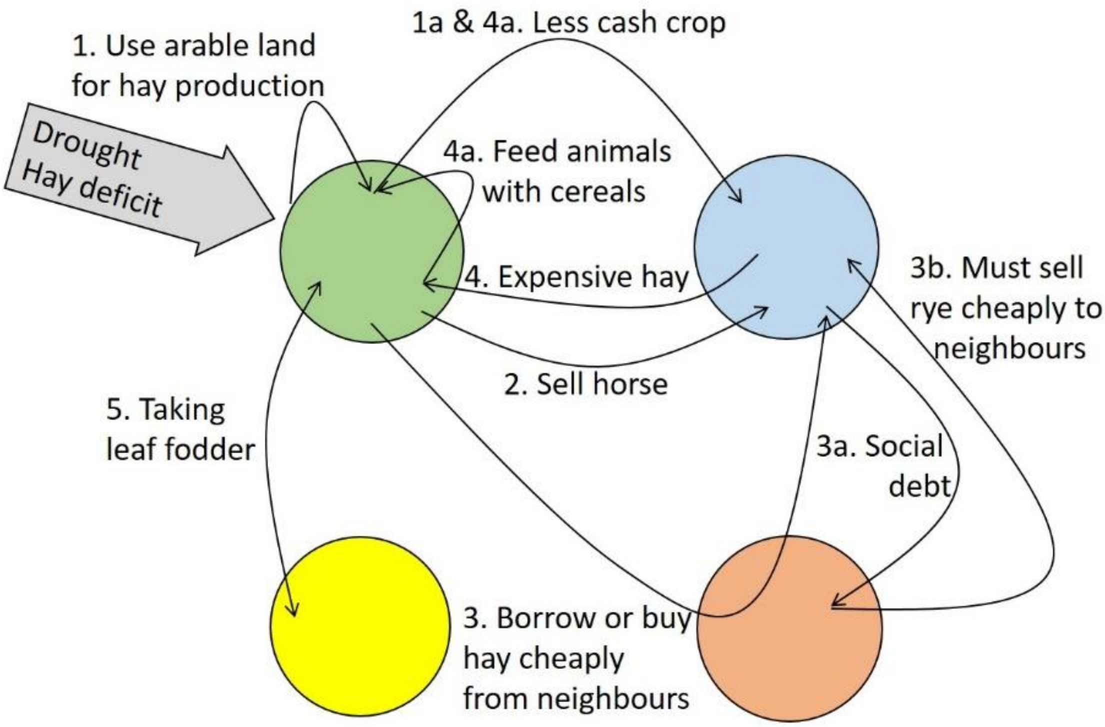


Figure 2.17. Some activities, and their effects, performed by Muncktell's household related to hay deficit during the period 1814–1821. Activities are related to the four main domains (see Figure 2.28). See the text for further explanation. From Lennartsson et al. 2015)

Figure 2.18 summarizes all the activities following hay deficit. By relating activities to domains, SES makes it clear that the deficit of hay was handled mainly through Muncktell's relations to the higher social groups, from whom he could borrow or cheaply buy hay. Muncktell's actions were thus mainly aimed at accommodating shortfalls of the hay supply, rather than to increasing his own supply. Some measures were taken for improving the drying of hay, i.e. for reducing the fluctuations, but hardly any significant actions were taken to increase the total hay resource.

In contrast, the shortage of pasture (see Lennartsson et al 2015), initiated labor-intense actions that were possible because of the availability of cheap labor. Most of the actions were aimed at extending and improving the farm's own pasture, e.g. clearing new pastures, both to overcome the immediate problem and for reducing the risk of future pasture deficit.

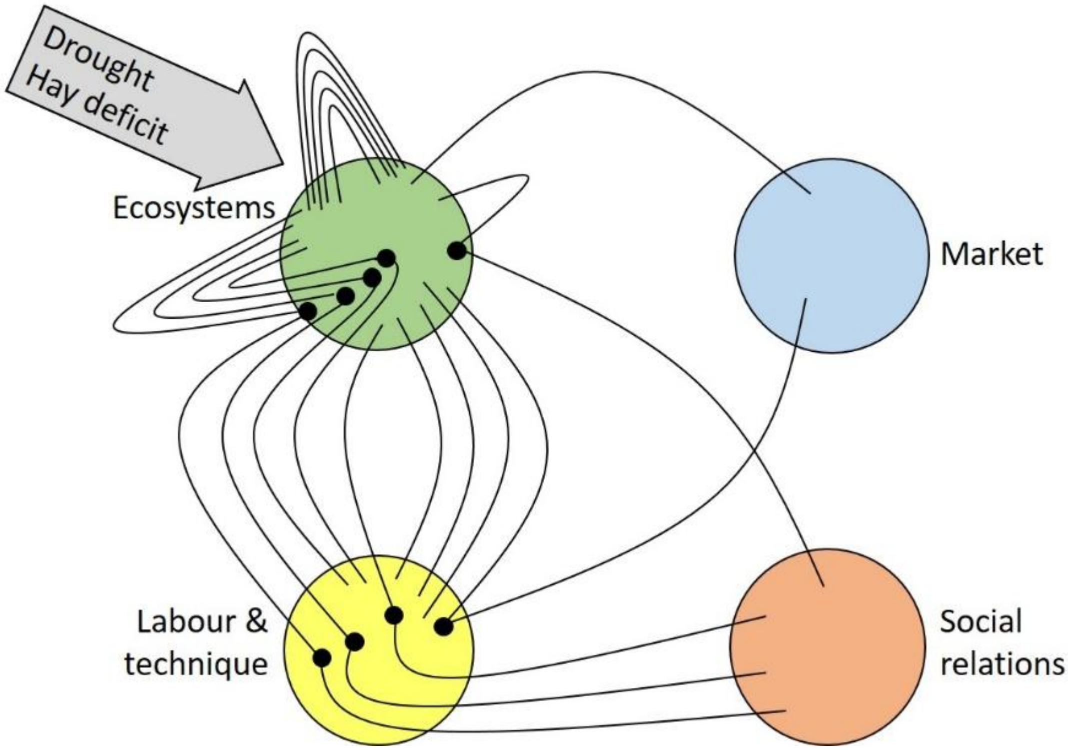
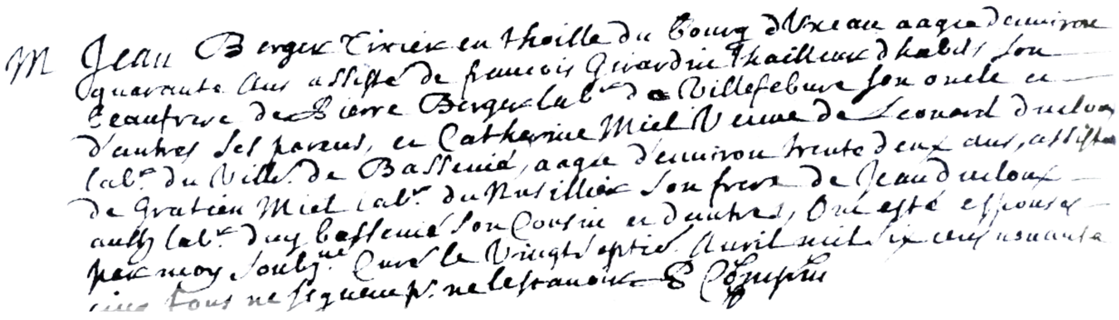


Figure 2.18. Graphic representation of all activities, and their effects, performed by Muncktell's household for handling the deficit of pasture hay, 1814–21. For simplicity, the lines show only the interactions between domains, not the direction of the interactions.

Example 3. Parish records reveal ecotypes in late 17th century France.

In our long-term research project in Burgundy, France, we have made use of large amounts of documentary data about land use, economy and more. Among many other tasks, we have integrated the detailed cadastral (land ownership) maps with the associated tax data in our project GIS (Madry et al. 2015). It is difficult to find historical data directly related to land use parcels for time periods before the mid 17th century. Although there is tax information about individual parcels from the 1791 onwards, it is difficult to use this to reconstruct all land worked by individual households. This is due to the fact that much of the land was farmed by large, communal sharecropping households (*communautés*), whose land was mixed with land owned by individual members of the communauté, and also land owned by the elites in the surrounding towns who leased their land on a sharecropping basis. For earlier periods, it is difficult to find any historical data relating directly to local land use. Parish records offer indirect possibilities to address questions about land use, subsistence and social relationships.

In order to take our land-use study as far back in time as possible, we used parish records with the oldest complete records available, from the 1690s (Jones 2009). Parish records contain information about baptisms, marriages, and burials together with the age, residence and occupation of the family members (Figure 2.19). In addition, information was given about the marriage witnesses, mourners at burials, and godparents, and also for these peripheral persons often the residence, occupation and relationship to the family member were accounted for.



Jean Berger, weaver of the town of Uxeau, aged about 40 years assisted by François Girardiu, tailor, his brother-in-law and by Pierre Berger, plowman of Ville Fèvre his uncle and others, his relatives and Catherine Miel, widow of Léonard Ducloux plowman of the village of Bassenier, aged about 32 years, assisted by Gratien Miel, plowman of Nusillier, her brother and by Jean Ducloux, also plowman of the said Bassenier, her cousin and others, were married by me the undersigned Curé the 27th of April 16, 1695, none of whom signed except François. P. Compin

Figure 2.19. Example of wedding entry from 1695 Uxeau parish records with translation.

The commercial genealogy software Family Tree Maker was used to create 'family reconstitutions', basically doing genealogical research (i.e. making family trees) for the entire parish. Reports were generated that were customized and exported to Excel spreadsheets and relational databases for further statistical analysis and integration with our project GIS database (Jones 2009).

The study area (Figure 2.20) consisted of a lowland area (parish of Bessy) and an upland hill country around Mont Dardon (parish Uxeau). The 1690s was a very cold decade with large variation in weather patterns resulting in the last great famine in France. Since people in Uxeau survived these crises better than most in the surrounding areas, it is also interesting to search for possible successful farming strategies indicating models of resilience and sustainability.

In the 1690s the parish consisted of 17 communautés and 10 non-communautés including 4 small family farms, 2 villages, 3 mill sites, and one industrial hamlet. The main farming activity was growing grains, mostly consumed locally. Mills had to be plentiful because the wagons were few (groups of neighbors often shared a single wagon), and roads were bad, preventing long distance transport. The mills (four altogether, with one mill being part of a communauté) were all situated along a certain elevation line or fall line, in Uxeau (Figure 2.21). Vineyards were also located at a similar elevation along the well-drained slopes in Uxeau below Dardon, and the lowlands of Bessy had no wine growers.

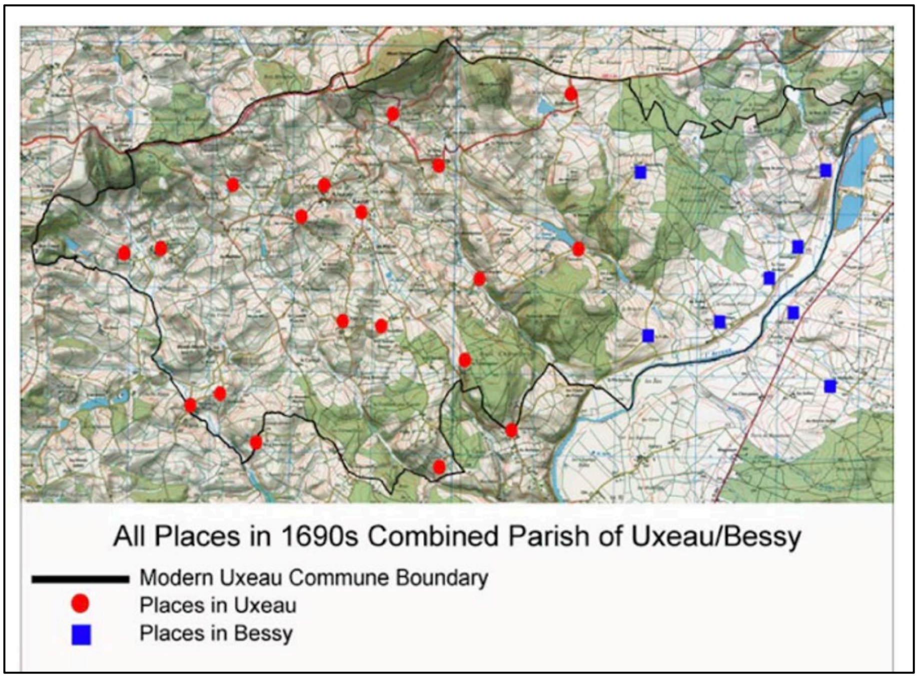


Figure 2.20. Modern topographic map showing all occupied places present in the 1690s parish records, indicating uphill Uxeau (red) and lowland Bessy (blue) and the modern commune border. Background map courtesy IGN.

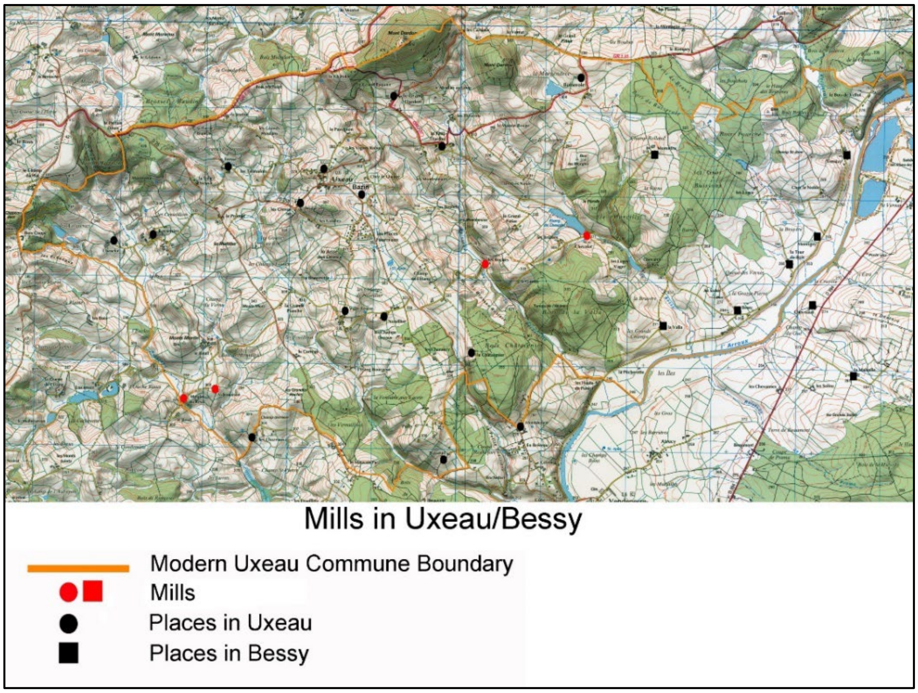


Figure 2.21. Map showing mill sites present in the 1690s parish records, with mill sites is red. Background map courtesy IGN.

Animals were absolutely essential in order to provide manure for the fields. The households also needed to raise some kind of homegrown fiber for clothing. In the uplands of Uxeau, sheep could graze on the rocky and steep land unsuitable for farming and they gave both manure and fiber (Figure 2.22). In lowland Bessy, those purposes were served by growing hemp and the fattening of retired plow oxen which eventually were sold to the towns for meat.

The maps derived from analyzing the 1690s parish records show two distinct ecotypes. An ecotype (Mitterauer 1992:142-143) encompasses:

- the local environment and its range of available resources
- the particular resources that are extracted and the type of technology for doing so
- the sociocultural institutions for instituting and organizing the family as an integrated workforce
- the local relations between peasant farmers and non-peasant groups (e.g. the nobility, village tradesmen and craftsmen, day-laborers, etc.)
- the interrelations between groups exploiting different resources within the same environment
- and the relations of the local area to outside areas which include transportation networks, settlement patterns, and the macro- political and economic systems

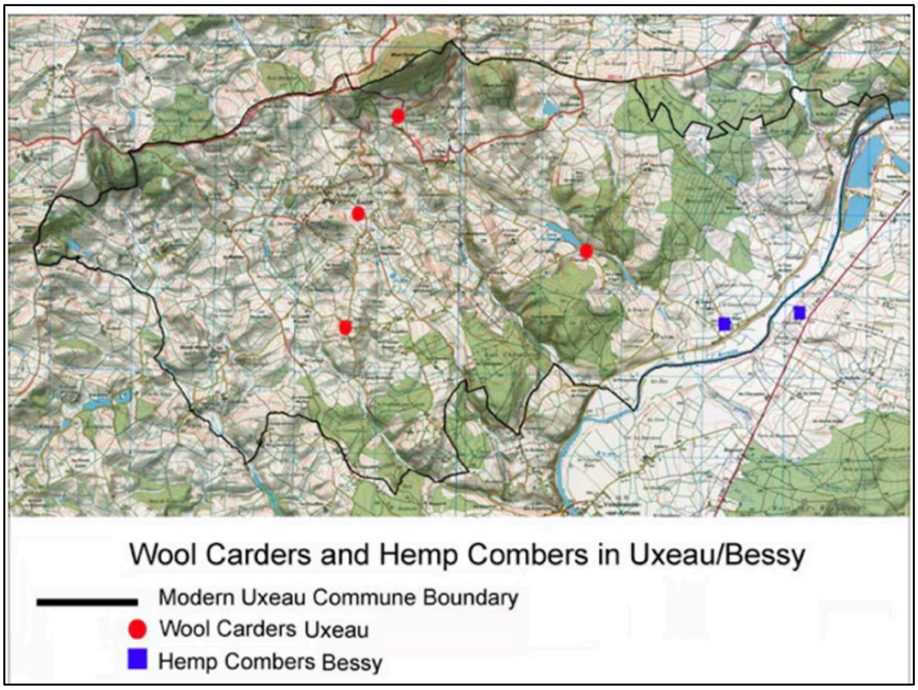


Figure 2.22. Wool carders in Uxeau and hemp combers in Bessy. Background map courtesy IGN.

The two different ecotypes in Uxeau and Bessy hilly uplands and riverine lowlands, and the differential extraction of resources from the environment in this period were also mirrored in the social relationships. The 1690s was a period of climatic upheaval, high taxes, and epidemic disease. At this time, marriage and godparent relationships were often established with people outside their home parish. Alliances outside the one's parish could serve to mitigate risk in times of local crop failure or from the loss of a sharecroppers' contract which resulted in loss of home and land to farm. Alliances were also often established within their own parish but, interestingly, they were rarely established between the two parishes of Uxeau and Bessy.

The different ecotypes offer a possible explanation. Although Uxeau and Bessy had in common that they were growing grains, and many people in both parishes belonged to a large communauté, they were engaged in different kinds of supplemental income activities. The segregation in differing economic activities, rooted in their respective landscape types, may have caused them to travel in different social worlds. Alliances may have formed more easily, and were more helpful against risk, with people that shared the same economic activities, activities that were shaped by the resources available to them in their distinct ecotypes.

The two historical ecotypes follow the topographical differences in the landscape, but today there is no highland-lowland economic difference that would have hinted at this historical difference. Today, both the Uxeau and Bessy land areas are covered with same pastures and fodder crops while vines are now absent throughout. The family reconstitution made in the 1690s revealed much about the connections between ecotypes, historical land-use and social networks in Uxeau, providing new insights into the Historical Ecology of this area.

Limitations and benefits of working with documents in Historical Ecology

Benefits:

- Pre-industrial societies relied on sustainable ecosystems, and most documentary sources therefore, have perspectives relevant to Historical Ecology research.
- Written statements contain information about special occasions as well as everyday life in past times that would otherwise be inaccessible to us today.
- Authorities have often collected consistent data which enables comparisons in time and space, and also the amount of data that allows interpretation and contextualization.
- Many countries have rich archives. The Swedish National Archive alone keeps over 700,000 shelf-meters of documents and 5.7 million maps and drawings. A large portion of these documents have not yet been researched. The French archives are constantly adding new historical documents to their online inventories making this information available for free anywhere in the world. Imagine all the interesting information that waits to be explored.
- Multiple text sources provide for comparisons and cross-checking of data and finding errors, anomalies, and outliers in the information.
- Textual data such as cadastral taxes and land ownership can be spatially integrated in a project GIS system.

Limitations:

- All sources were produced for a specific purpose, and rarely match exactly the specific questions of interest for the researcher. Therefore, it is always necessary to ask how well suited the information is for the research question. Perhaps there are other more relevant or complementary sources to work on?
- Some sources provide useful time series which cover long time periods, while others appear only once or perhaps a few times during a longer time period. Between these occasions, perhaps the intention and instructions have changed, which makes them difficult to compare. It is important to consider if differences are due to real changes or changes in documentation.
- Spatial cover of sources differs between regions, class, and due to shifts in national or internal political borders.

- Data has been lost when some archives have been destroyed by fire, war, or floods.
- Despite a growing number of digitizing projects where archives and museums put more and more documents online, most of the documents are only available in the archive where they are cared for. Working with the documents in archives have many advantages but it is also time consuming, compared to working with digitized documents online.
- Gender, class and ethnic biases are present in most sources. Most documents were written by men, about the male economic sphere and from an authority perspective. E.g. There is much more information about the typical male domains: land ownership, arable land, mining and forestry, than on female domains: household, cows, textiles etc. although they were of equal economic importance. Rarely do we hear the words of women, farmers (of both sexes), and even more rare from poor people.
- "Silent" knowledge, folklore, beliefs, fears and feelings, are almost always absent in these documents, which of course tends to be underestimated in our knowledge about past living. For example, among the factors important for where to place a summer farm were: good pasture land, water, availability, but also if the place was haunted by spirits or was considered in an auspicious location.

Best practices, data access, archiving, sharing and storing

Many of the best practices in dealing with historical documents have been covered above. There are additional considerations particular to historical documents, including dealing with confidential data, storing and sharing personal information, translation, translating, state of preservation, legibility or paleography issues working with hand-written documents, and many more that we have not covered here. For fragile paper documents in a poor state of preservation, it is better to photograph the document than to keep handling it. Photos of the document can also be manipulated in photo editing software to enlarge and heighten the contrast on faded script to make the image more legible.

Most institutional archives generally give open access to their collections. However, some archives have restricted hours of operation, and may also be slow in fetching the sources from the storerooms (which may be off-site) where they are kept safe, which can be frustrating if you are time-limited. Some require registration, including letters of introduction and proof of professional affiliation and your research interests. A growing number of archives now allow open access for publications, while some retain copyright ownership and require written permissions or fees for publication or photographing. On the other hand, sources are becoming increasingly accessible online, to both find, view, download, and share.

Proper archiving of both paper and digital data are vital, once you have acquired and analyzed them. Modern digital archiving systems provide for attribute-tagged digital databases of multiple types of data, including documents, and this is covered in chapter 15. Each chapter in this volume also deals, to some extent, with archival documents, and don't forget that each document you create is itself an archival document worthy of proper conservation and preservation for future researchers. Historical data can be stored, shared, and analyzed both in original paper as well as in scanned digital formats. Data can be easily shared digitally, but we must take care to address any copyright or reproduction issues.

It is also important to ensure that the resulting data are shared not only through academic and professional means, but also with the heirs and families when working with family archives, oral data, etc. These data derive from local communities, and it is generally much appreciated when researchers share back information with these communities. Publishing can also be done in more accessible formats, popular magazines, local museums and exhibits, and local oral presentations to the public. This can also include the now ubiquitous websites, blogs, and webinars.

Cost and effort required, training needed, data size, complexity issues, and software required

The cost of historical documentary research is generally measured in time and archival access costs such as travel or possibly in the purchase of original historical copies. Training in paleography, the skills of deciphering and reading ancient to early-modern manuscripts, may be required for hand-written documents, as well as learning to read the language of the document, including local dialects. While much documentary research is done simply with pen, paper, and camera, quantitative analysis is becoming more and more common using statistical analysis, genealogy software, spreadsheets like Excel, relational databases, and qualitative analysis software, such as Atlas.Ti. The data are relatively small and less complex and can often be integrated with spatial data in a GIS. Thought should be given to how documentary data can be shared and integrated with other data from other sources, as discussed in chapter 17.

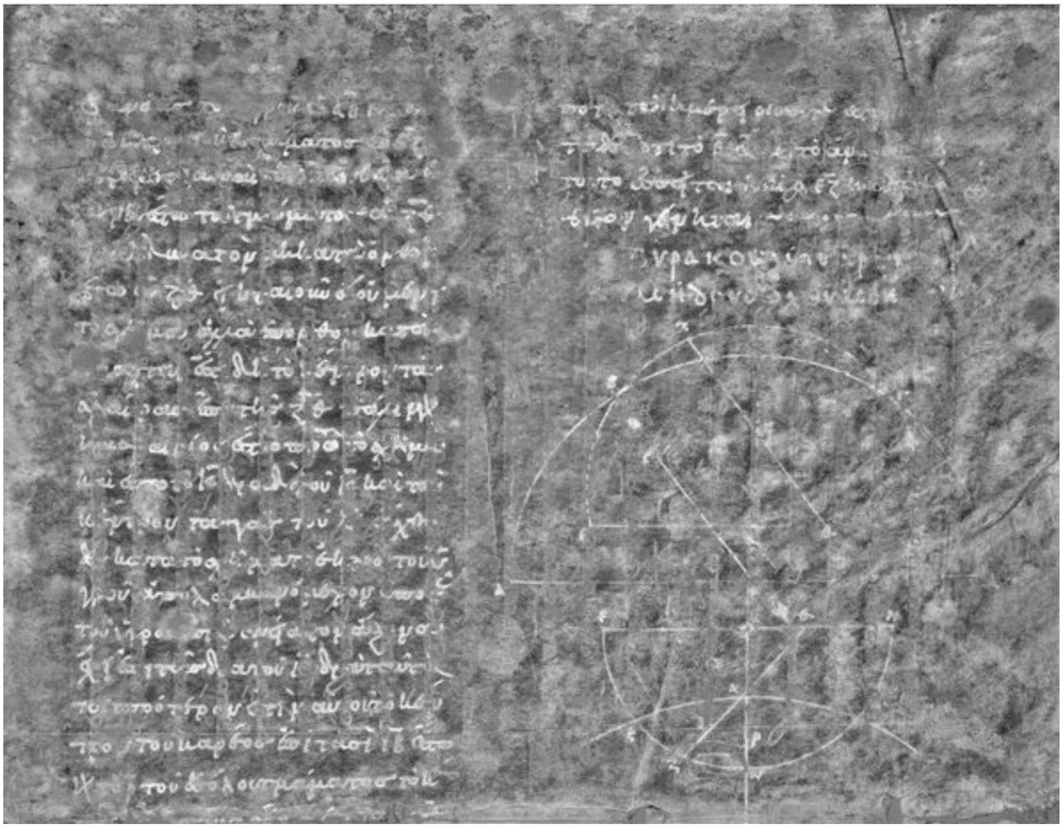


Figure 2.23. An X-Ray radiograph of the Archimedes Palimpsest, showing details not visible with the eye. https://commons.wikimedia.org/wiki/File:ArPalimTyp2.jpg

Future Directions

The newly emerging field of Document Image Analysis and Recognition (DIAR) uses well established and emerging multispectral digital scanning, image analysis, deep learning, AI, and feature recognition for the reconstruction and analysis of historical documents which may be damaged, burned, faded, or copied over (Lombardi 2020a, Mariana and Fujisawa 2008). Imaging a document in X-Rays, infrared, and other portions of the spectrum and conducting digital image processing of the data can bring out faded details and make illegible documents readable (Figure 2.23.). Many documents now are being reconstructed or made readable by scanning them with advanced, multispectral scanners and using digital image analysis, Deep Learning and Artificial Intelligence (AI) to extract and view the content (Lombardi 2020b). Other documents are being translated, reconstructed, and dated using these new approaches, and there will certainly be more advances in this exciting area. This emerging field holds great potential for the rapid deciphering of thousands of damaged, copied over, or difficult-to-read handwritten historical documents. The recent Google DeepMind AI project named Ithica can be used online to decipher ancient Greek texts using neural networks with a 71% accuracy and can even make a prediction of the location of the origin of the text and can predict the date to within 30 years. (https://www.techeblog.com/google-deepmind-ai-artificial-intelligence-ancient-text/).

We also note that in this digital age it is uncertain how historical document analysis of our own time will be able to be conducted in the future, as our generations are leaving very little analog data for future researchers.

Conclusions

Historical documents can be used for a variety of research questions relevant for our understanding of past interrelationships between humans and the ecosystems in which our ancestors lived. In this chapter we have dealt with several of the main sources of data we ourselves are familiar with from our countries and fields of research, means of analysis, and issues relating to their use. We have presented several, brief case studies to illustrate how they can be used and what types of limitations there are. There are also many other types of documents that may be useful in Historical Ecology. Anything that has been considered important enough to be committed to paper may have been kept in archives or elsewhere, for us to read or view today. Many of these past testimonies offer portals to the past. Although working with the documents themselves is very rewarding, they may be even more useful in combination with other types of sources such as archaeological and ecological field data, oral information and cartographic sources. We want to acknowledge, however, that many voices from the past have never been conveyed to the afterworld. In the long view historical perspective, literate people constitute a small proportion of past populations, and history has therefore mainly been told by the people with power and societal positions. Direct testimonies from children, women, poor people and farmers are much rarer, but they sometimes emerge through other people's writing. Likewise, ecosystems are also illiterate, in the sense that they did not write their own history. In that sense the ecological side may be harder to understand through documents than the human side of Historical Ecology. Interestingly though, ecosystems are their own living archive, which can be read and understood in the field. This is explored further in chapter 3.

References

Barber, R.J. & Berdan, F.F. (1998). The Emperor's Mirror: Understanding Cultures through Primary Sources. Tucson, Arizona: University of Arizona Press, 1998.

Campbell, B.M.S. & Bartley, K. (2006). England on the Eve of the Black Death: An atlas of lay lordship, land and wealth, 1300-49. Manchester University Press: Manchester

Cunfer, G. (2005). On the Great Plains: Agriculture and environment. Texas A&M University Press: College Station

Dahlström, A. (2006). Betesmarker, djurantal och betestryck 1620-1850. Naturvårdsaspekter på historisk beteshävd i Syd- och Mellansverige (Pastures, livestock numbers and grazing pressure 1620-1850. Ecological aspects of historical grazing in South- central Sweden). Acta Universitatis Agriculturae Sueciae 2006:95, Doctoral Thesis Swedish university of Agricultural Sciences

Debussche, M., Lepart, J. & Derviewux, A. (1999). Mediterranean landscape changes: evidence from old postcards. Global Ecology and Biogeography Letters 8(1): 3-15.

Gadd, C.-J., & Jorner, U. (ed.). (1999). Svensk jordbruksstatistik 200 år. Statistiska centralbyrån, Örebro, Stockholm.

Jones, E. (2009). Multi-temporal Landscape History in Burgundy: An Innovative Application of Genealogy Software in: Making history interactive: Computer Applications and Quantitative Methods in Archaeology (CAA): proceedings of the 37th international conference, Williamsburg, Virginia, United States of America, March 22-26, 2009

Jordbruksverket & Statistiska centralbyrån. (2011). Jordbruket i siffror åren 1866-2007. Sveriges officiella statistik.

Kyvig, D.E. & Marty, D.A. (2000). Nearby History: Exploring the Past Around You. Second Edition. Walnut Creek, California and Lanham, Maryland: Altamira Press, 2000.

Lancaster, L. & Bodenhamer. D. (2002). "The Electronic Cultural Atlas Initiative and the North American Religion Atlas" in Knowles A.K. (ed.) Past Time, Past Place: GIS for history ESRI Press: Redlands, CA, pp. 163-178

Lennartsson, L., Westin, A., Erikson, M., Flygare, I. A., Isacson, M. & Morell, M. (2015). Between nature and society – interpretation of an early 19th century farmer's diary. Agricultural History Review 63(2):265-285
Lombardi F, Marinai S. Deep Learning for Historical Document Analysis and Recognition-A Survey. J Imaging. 2020 Oct 16;6(10):110. doi: 10.3390/jimaging6100110. PMID: 34460551; PMCID: PMC8321201. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8321201/

Lombardi, F. & Marinai, S. (2020). Deep Learning for Historical Document Analysis and Recognition—A Survey. J. Imaging 2020, 6, 110. https://doi.org/10.3390/jimaging6100110

Lorenzen-Schmidt, K.-J. & Poulsen, B. (2002). Writing peasants: studies on peasant literacy in early modern Northern Europe. Landbohistorisk Selskab

Madrys, S., Jones, E. Tickner, A. & Murray, S. (2015). Water and Landscape Dynamics in Southern Burgundy: Three and a Half Centuries of Water Management in an Agricultural Landscape Journal of Water History 7(3):301-335.

Marinai, S. & Fujisawa, H. (2008). Machine Learning in Document Analysis and Recognition. Springer Berlin, Heidelberg https://doi.org/10.1007/978-3-540-76280-5

Mitterauer, M. (1992). Peasant and Non-Peasant Family Forms in Relation to the Physical Environment and the Local Economy. Journal of Family History 17(2):139–159.

Östling, P.-A. (2010). Dialekt- Och Folkminnesarkivens Material : Etnobiologi På Institutet För Språk Och Folkminnen (SOFI): Exemplet ULMA, in Nycklar till Kunskap : Om Människans Bruk Av Naturen (Stockholm: Nycklar till kunskap : om människans bruk av naturen 2010, 2010), S. [67]-72.

Paxion, K., & Cohen, O. (2002). Wissant Bay: 100 years of change in pictures (La baie de Wissant: Cent ans d'evolution en images). Mappemonde 3: 24-27.

Pinol, J.-L. & Garden, M. (2009). Atlas des Parisiens: De la révolution à nos jours. Parigramme: Paris

Poirier, J. (ed.) (1968). Histoire de La Pensee Ethnologique, in Ethnologie Générale. Paris.

Sawyer, C. & Butler, D.R. (2006). The Use of Historical Picture Postcards as Photographic Sources for Examining Environmental Change: Promises and Problems, Geocarto International, 21:3, 73-80, DOI: 10.1080/10106040608542395

Spence, C. (2000). London in the 1690s: A social atlas. Centre for Metropolitan History, Institute of Historical Research: London

CHAPTER 3

BIOLOGICAL CULTURAL HERITAGE

USING BIOLOGY AS A SOURCE TO HISTORY

ANNA WESTIN, EVA GUSTAVSSON, TOMMY LENNARTSSON

This chapter will introduce a method for the use of biological cultural heritage (BCH) as an historical source. In most places where people have been active, they have left traces in nature, intentionally or unintentionally, which constitute a biological cultural heritage. Examples are occurrences of plants and animals that are favoured or actively introduced by humans, trees scarred by former leaf cutting or grazing damage, remnants of vegetation from an abandoned pasture, entire human-formed landscapes, and much more. BCH is probably the most widespread type of cultural heritage outside of urban areas. Interpretation of such traces uses ecological knowledge about how species and individual trees react in natural and culturally shaped conditions, in combination with historical knowledge about former human activities, from sources such as historical documents, oral information, archeological knowledge, aerial photos etc. The method of interpretation weaves together the different kinds of information in a stepwise procedure in order to increase the knowledge about how humans depended on and shaped ecosystems. We exemplify with case studies from Sweden and Central Europe.

Introduction

History is present everywhere in the landscape, in dead objects as well as in living organisms. The shape of every tree and bush, the presence of every plant and insect has a story to tell about the past, about which conditions have shaped or allowed their presence in a particular place. Many of these conditions are mainly natural, such as different aspects of climate, soil and bedrock, and natural ecological processes. However, by interacting with the natural world, humans have modified these ecosystems. Ecological conditions have thus frequently been altered or entirely created by humans, either intentionally, such as clearing of forest, drainage, and planting of trees, or unintentionally as side effects of land-use, such as the effects of cattle grazing on plant communities.

Traces of modified ecosystems can persist for some time as a biological cultural heritage (BCH) after the land use in question has ceased (e.g. Figure 3.1). In this respect, BCH parallels other, more well-known types of cultural heritage, such as remnants of buildings, former stone fences, and burial mounds. BCH, in contrast, consists of living organisms as carriers of historical information. In this chapter, we introduce the concept and discuss how living organisms can be used as historical sources. We argue that information from BCH can deepen the understanding of both history and nature, not least by providing insights in how to study and preserve landscapes' cultural heritage as well as biodiversity.

Figure 3.1. The distribution of meadow buttercup (*Ranunculus acris*) reveals the older location of a road in a current pasture in Skepptuna parish close to Stockholm. It lies close to a runestone and several grave mounds from the Iron Age, indicating at least a thousand-year history of roads in this location. Photo: Anna Westin

Definitions

BCH is manifested in the physical landscape mainly as the occurrence of species, combinations of species, genetic varieties, biotopes, and the shape of woody plants.

BCH is defined by the Swedish National Heritage Board (2020) as ecosystems, habitats and species which have originated from, or been shaped or favored by human utilization of the landscape and whose long-term persistence and development is dependent on, or favored by continued management. According to the Swedish heritage Board, BCH can appear at different scales:

- Traits of species. Genetic modifications, either derived through plant or animal breeding, such as fruit varieties, garden plant varieties, livestock breeds (Figure 3.2), or adaptations of wild species to management, such as the flowering time in Gentianella in relation to timing of mowing.
- The growth form of individual woody plants, i.e. shrubs and trees. Plants with woody tissue preserve physical modifications caused by, e.g. leaf harvest or other pruning, bark peeling, and light conditions (Figure 3.4).
- Occurrences of species at certain places. Humans have intentionally or unintentionally favoured certain species through creating suitable habitats or introducing plants and animals to new places (Figure 3.15).

- Habitats (biotopes). Through land use, humans have shaped new habitats with specific communities of plants and animals, e.g. pastures and hay-meadows. Gardens, parks and similar areas constructed using plant material, belong to this level of BCH (Figure 3.3).
- Landscapes. Several habitats together form entire human-influenced landscapes, sometimes referred to as "domesticated landscapes".

The definition above focuses on biological features and we use the term biological cultural heritage to emphasise that it is just another type of cultural heritage from the past. The similar term biocultural heritage is used in literature both for the biological features of culture, but also with a wider meaning to denote entire knowledge systems where indigenous people or local communities are seen as inseparable from nature, being in an intimate ongoing relationship with nature through e.g. land use, rituals and beliefs (e.g. Gavin et al. 2015, Swiderska 2020). This use of BCH includes both past and ongoing human-nature practices and its physical manifestations in nature.

Figure 3.2. Daffodils (*Narcissus pseudonarcissus*) found next to the ruins of a small cottage in Krösås, county of Jönköping, Sweden. Occurrences of garden flowers are the result of intentional cultivation and can therefore indicate human settlements when found in unexpected places. It can be related to gardening trends of various time periods. This old variety of daffodil is no longer available in plant stores and constitutes a BCH in itself, at the genetic level. Photo: Anna Westin 2022.

Cultural heritage can be viewed as the physical manifestations of human culture in the past: a mound, ruin, architectural details of a building, an apple cultivar and a place with hay meadow vegetation. This is how we use the term BCH in this chapter. Cultural heritage, as well as BCH, may, however, be used in a wider sense, denoting our entire cultural heritage, including art, literature and intangible heritage such as traditions, perceptions and place names. Some researchers have adopted this wider use also in BCH, for example the archaeologists Karl-Johan Lindholm and Anneli Ekblom (2019), who define BCH as "an understanding of cultural landscapes as the result of long-term biological and social relationships, shaping the biological and material features of the landscape and also memory, experience and knowledge".

Intangible cultural heritage, such as place names and traditional ecological knowledge referring to biological features, is often included in the term BCH (e.g. Rotherham 2007). Our use of the term biological cultural heritage includes biological features that can be interpreted to tell about past human activities of any kind. It is not restricted to certain groups of people or contexts.

Conceptual background

Human-nature interactions

BCH is formed through an interaction between humans and nature, where nature may be anything from landscapes to genetic material of crops and livestock. However, apart from genetic varieties of plants and animals, and constructed gardens and parks, most of the BCH emerges from human use of ecosystems and is found throughout the landscape. The interest in how people have formed ecosystems goes back long before the term BCH came into use. By transforming natural ecosystems, the provisioning of natural resources can be enhanced, mainly through change of vegetation. One example is the transformation of sparse ground vegetation in forest into more productive vegetation in open grassland or semi-open forest. In order to maintain productivity of ecosystems, locally adapted methods for influencing vegetation have been developed, such as various types of coppicing, watering and burning.

Conceptually, transformation of nature to meet the needs of human populations is the basis of boserupian theory for subsistence (after the Danish economist Ester Boserup; see e.g. Fischer-Kowalski et al. 2013). However, such theory focuses mainly on technical development and geographic expansion of land-use, while measures for working with natural vegetation processes in semi-natural ecosystems are less studied.

Since the variety of techniques for manipulating ecosystems is interrelated with the response of the ecosystems' biodiversity, the concept of biocultural diversity is highly relevant for our understanding of human-nature relationships (Crumley et al. 2018; Maffi & Woodley 2010). As the diversity of methods for forming and using ecosystems increase, so do the cultural manifestations of land-use in language, traditions, poetry and so on, i.e. the cultural diversity. And so does, in most cases, the biological diversity, for example in terms of diversity of species and biotopes. Hence, the more diverse use of natural resources, the larger diversity of BCH. Interpreting species, vegetation and biotopes as BCH is largely a question of understanding specific links between biological phenomena observed in nature and the local culture that depended on and formed the ecosystem where the phenomenon is found.

Another research approach for describing human-nature interactions is the framework of social-ecological systems (SES), which emphasizes the links between biophysical and social factors (Berkes & Folke 1998). An example of the use of SES in Historical Ecology is presented in Chapter 3 (from Lennartsson et al. 2015).
How can living organisms become a legacy of past conditions?

The basic requirement for a BCH to form is that the disappearance or response of living organisms is delayed compared to the change of human activities that have been responsible for the organisms in question. For example, ornamental plants survive for some time in an abandoned garden, as do meadow plants after cessation of mowing. There are several biological mechanisms that account for such inertia. One is that the environment itself changes slowly and thus maintains favourable conditions for land use-dependent species long after land use has changed or stopped. This is, in particular, the case in low-productive environments, for example in mountainous climates, or on dry or poor soils. Such regions may therefore be especially rich in BCH.

Other causes of delayed response are attributed to the organisms themselves. Many plants are long-lived. Trees and shrubs keep their woody tissue all year round, perennial herbs and grasses survive the winter underground, and short-lived plants survive from generation to generation as seeds.

A typical scenario when traditional land-use (for example grazing) ceases is that the vegetation composition changes rather rapidly (it is no longer a pasture vegetation), whereas populations of many single plant species disappear much slower (some pasture plants remain). The most resistant species may still be found as relict populations when the habitat is completely gone (the pasture has turned into forest). As a result, the vegetation in a landscape usually consists of both species belonging to the present habitat and conditions, and species that are a legacy of earlier conditions – some from the more distant, some from the more recent past. A study of the flora in the province of Västergötland, Sweden showed that land use in the mid-18th Century (known from cadastral maps) explained the distribution of the present flora better than any subsequent time periods, including the present-day (Gustavsson et al. 2007).

Figure 3.3. The species composition of plants in this Swedish hay meadow have been shaped by hundreds of years of management. The vegetation interpreted is a historical source to mowing and other traditional practices of hay management. Photo: Tommy Lennartsson.

Many plant species build up a seed bank in the soil, which may constitute an extremely long-lived BCH. Through the seed bank, species can survive during periods too unfavourable for even the most persistent plants. If suitable conditions return, plants may emerge again (for example if the overgrown former pasture is logged). Animals are not as long-lived as plants but may survive changes of environment by moving to more suitable habitats. Such species thus indicate earlier conditions in the landscape, if not necessarily on the spot where they are found. One typical example is that sun-demanding insects have moved from sparse forest pastures to the forest edges when grazing ceased, and the forest became too shady. Mobile organisms may therefore be a type of BCH that can remain in a landscape where many other types of cultural traces are destroyed.

Biological cultural heritage in research

BCH consists of living organisms that can be interpreted to reveal information about human history. Similarly, paleoecologists and archaeologists interpret dead remnants of species present, as pollen and macrofossils (Chapters 4 and 8).

Early ethnologists often studied rural communities being dependent on their local ecosystems, and the understanding of how people related to and used nature was a common focus of ethnological research. Some ethnologists were skilled nature observers who could describe human shaped ecosystems in detail, e.g. by presenting species lists from the wild versus human-influenced vegetation (in Sweden one representative is the geographer John Frödin 1952, 1954).

Early researchers in ecology, by contrast, usually excluded human influence from their studies of nature. Studies of ecosystems and species instead focused on the effects of natural conditions such as nutrient stress and hydrological conditions, or natural processes such as evolution, competition between species, and succession towards "mature states" of nature. Also, early nature conservation had a focus on wilderness and natural ecosystems, even in places where many of the biological constituents were clearly created by humans. We believe that even today in ecology, historical land-use as an ecosystem-forming agent is somewhat overlooked, especially in forest, wetland, and mountain ecosystems (e.g. Eriksson 2018). The historical background and human influence in agricultural landscapes is better known and the perception of these landscapes as BCH is therefore uncontroversial.

Aspects of historical research, especially within rural history, agrarian history and Historical Ecology, focus on people's relationships with, use of, dependence on, and alteration of natural resources. It is still rare that BCH is used as a source in Historical Ecology and methods for doing so are still under development. Scattered examples can, however, be found in both pioneering and recent research, for example in forest history.

Oliver Rackham studied the Historical Ecology of British woodlands and developed the concept of ancient woodland, managed through traditional practices. He showed how today's British woodlands are partly artifacts, and that traditional land-use generated conditions for a rich plant diversity. Rackham's analyses combined multiple sources such as pollen analysis, archaeology, botanical fieldwork, written sources, practical experiences and oral tradition (Rackham 2003). In Italy, Roberta Cevasco and colleagues studied alder (Alnus) dominated woodland. They used interdisciplinary methods to uncover the history of an abandoned land-use called Alnocoltura, where alder (*Alnus incana*) was managed in rotation with cereal cultivation and grazing (e.g. Cevasco 2010). In woodlands of the far north of Sweden. Lars Östlund and colleagues have mapped and interpreted pine-trees marked by bark peeling, mainly by the indigenous Sami people. Their studies prove long-term human presence in woodlands which ecologists frequently regard as more or less pristine (e.g. Östlund et al 2003).

Cultural heritage scholars and practitioners have a tradition of working with non-living remains and traces, such as building sites, stone walls, shipwrecks and ditches. In some cases, ancient trees with a specific history were denoted as "natural memory" already in the early 20th century. Such trees were old and impressive and/or were connected with oral history, local tradition, folklore, or specific events.

The term biological cultural heritage (or more commonly biocultural heritage), has mainly come in use during the last twenty years (Table 3.1). Although the different disciplines involved in the interpretation of BCH have a long history, combining them in the context of BCH is a less explored field. The established interdisciplinary knowledge base is relatively small and methods are being developed along with new projects. Each study is more or less a pioneer work, and anyone who starts exploring this field has the potential to make important contributions.

In this chapter we discuss the potential of biological features in landscapes as historical sources, using examples from forest ecosystems.

Table 3.1. Number of hits at Google Scholar for the terms Biocultural heritage and Biological cultural heritage.

	Term	Number of hits	Of which in the title
1980-1990	Biological cultural heritage	1	0
	Biocultural heritage	5	3
1991-2000	Biological cultural heritage	5	0
	Biocultural heritage	4	6
2001-2010	Biological cultural heritage	23	0
	Biocultural heritage	156	109
2011-2022	Biological cultural heritage	147	5
	Biocultural heritage	3040	100

What can BCH tell us?

BCH connects history to ecology and can be used to find new insights into both historical and ecological questions - as well as their applied branches, cultural heritage conservation and biodiversity conservation. In history and cultural heritage conservation BCH constitutes an additional historical source material, most prominently for areas and activities in outlying lands where other cultural traces are few. In ecology, BCH introduces new (anthropogenic) ecological variables for understanding landscapes, habitats, and species. This is not the least important in biodiversity conservation, which often aims at restoring past, more beneficial conditions for biodiversity.

Before explaining the methodology, we will present some European examples of BCH often used for interpreting historical land-use, namely herbs, grasses, trees and bushes.

Herbs, grasses and vegetation

Plants are present nearly everywhere during the growing season and humans have used plants for themselves and their livestock throughout history. By collecting, cultivating, favoring, disfavoring and moving plants, humans have altered the vegetation wherever they have been. Some of these alterations can be traced for a long time and it is possible to "read" flora and vegetation as a source to history. Getting to know plants is like learning a language of nature. Just like languages have vocabulary, grammar and dialects that must be learned, also the plant language has key elements building up the knowledge such as identifying species and knowing their environmental demands and reaction to disturbance. By acquiring knowledge of plants, they can be used to understand both natural and cultural aspects of nature. For example, it is usually necessary to identify plants down to the species level in order to interpret them correctly.

Figure 3.4. Giant pollarded beech trees in a dense forest reveal the land use history as well as the former forest structure. This forest in Botiza in the Romanian Carpathians has probably been a pasture with scattered pollards, harvested for leaf fodder. Photo: Tommy Lennartsson.

Environmental conditions

Not all species appear everywhere. Although all plants share the basic needs of nutrients, water and light, they differ in terms of shade tolerance, drought tolerance, competition strength and reaction to disturbance. Different sets of species are therefore found in forests versus open lands, wet versus dry soils, nutrient rich versus nutrient poor soils, etc. Some species grow in a large variety of environments while others are restricted to more specific habitats, with the latter being better indicators. Environmental conditions should be understood at two different levels.

Essential conditions are those that must be present for a species to establish and reproduce. Once established, they may be able to persist for a long time as long as the conditions are tolerable. For example, many grassland species need good light conditions to establish, flower, and set seeds, but may persist as non-flowering specimens in shady conditions for a long time. If found in a forest they indicate that conditions were lighter in the past (fewer or no trees). Knowing the essential conditions is key to understanding what a place was like in the past. The tolerance of species explains their persistence to change and for how long they can remain in unfavorable conditions.

Figure 3.5. Trees are important in folklore and traditional medicine. In Scandinavia, trees with a naturally occurring hole in the trunk, could be used to remove disease from children by pulling them through the hole (Sw. smöjning/rotdragning) in Uppland Sweden 1918. Source: Nordiska museet (NMA.0034675) CCBY.

Disturbance

Ecologically, most types of land use practices can be considered as disturbances to the vegetation or soil. Plants may tolerate and even take advantage of disturbances such as grazing, fire and creation of bare soil. How different species handle disturbance is therefore another important aspect of knowing plants. Disturbance may be caused both by natural and cultural events. For example, many species may need bare soil to have a chance to establish, which can be created by fire, landslide, plowing, vehicles and trampling by wild or domestic animals.

Two central kinds of traditional land use are grazing and mowing. Through yearly removal of biomass, both grazing and mowing create and maintain light conditions, prevents litter accumulation, and remove and redistribute nutrients, thereby altering the interspecific competition (between different species). In addition to such basic environmental impacts, the detailed design of grazing and mowing may make specific imprints in the flora, especially the intensity, timing, and between-year variation of the management.

People and plant dispersal

The cultivation history of different species may reveal when plants were introduced into a region, how they were spread, how they were used, etc. Also, unintentional dispersal of plants can be traced by interpreting occurrences and distribution patterns. For example, transportation in winter required that hay was brought along for the oxen or horses. Seeds have fallen off along roads and at resting locations and enabled establishment of meadow species in new places.

Trees and shrubs

Trees and shrubs differ from herbs and grasses by building robust long-lived structures of wood. Not only are woody plants among the most long-lived organisms on Earth, the wood, i.e. trunk, shoots and branches can preserve traces of earlier conditions for as long as the specimen exists, dead or alive. The woody 'skeleton' grows differently depending on age, growth conditions, (access to nutrients, soil moisture, light, etc.) and whether they have been exposed to damage (natural or man-made).

Trees and shrubs have always been important in traditional livelihoods and may therefore contain many traces of former land use. Wild trees and bushes have been pruned or cut to provide for example timber, fencing material, firewood, and leaf fodder. Some tree species have been cultivated or otherwise favored for food, ornamental purposes, or cultural significance. Wild trees with peculiar shapes have also had an important place in folklore and for magical and medicinal reasons (Figure 3.5). Understanding how trees and bushes may constitute BCH, is a fundamental key to tracing not only the use of woody species but also land use influencing the environment in which they have been growing.

Because trees are long-lived, also the composition of tree species and the age distribution of stands may reflect earlier conditions, in particular, natural or anthropogenic disturbances such as fires, thinning or logging. When land is reforested after storm felling, felling by humans, or cessation of clearing, there is a succession process where different tree species replace each other. Pioneer trees such as birch, aspen and pine are replaced over time by secondary trees such as spruce, oak, and beech.

Trees and shrubs indicating light conditions

In an environment with more light, trees develop a low stature with wide crown and thick branches. This is applicable to all tree species, but more evident in some, like pines and hardwood species such as oaks and beech. Such a shape of trees thus indicates land use that has kept the environment open (Figure 3.6). If the land use changes and new trees establish, the thick branches die due to shading. Ultimately, only remnants of the old crown and stumps of branches are visible. Such damaged trees indicate an initial light period (when the crown grew wide) and a later shaded period (when the branches died).

In contrast, trees with tall stems, narrow crowns and thin branches indicate that they have grown up in shaded conditions (Figure 3.6). Shrubs and low-growing trees (e.g. rowan, *Sorbus aucuparia*, apple and hawthorn *Crataegus spp.*) are unable to grow in dense forest because they cannot compete with trees for light. Living or dead remnants of shrubs and low-growing trees in forest are therefore indicators of earlier lighter conditions.

By "reading" the shapes of trees in a forest and noticing remnants of shrubs and low-trees it is possible to trace land-use causing changes in forest structure going back hundreds of years.

Figure 3.6a and b Left: The old oak tree used to grow solitary and sun-exposed in a pasture and developed a broad canopy with thick branches. As grazing ceased, the pasture became overgrown and the old branches died from shade. Today, most of them are dead, but visible as scars on the trunk. Right; The pine in the middle grew up in a forest pasture with a scarce tree layer. It developed low stature and thick branches. When the use of the pasture stopped, a new generation of pines and spruces was established. Those trees have competed with each other for light and become taller without low branches. Photo: Tommy Lennartsson.

Pollarded trees, coppiced trees, stools and tree rings

After cutting, deciduous trees produce new shoots from the stump or roots. Pollarding of trees is repeated cutting of branches at some height above ground (Figure 3.7). All over Europe, leaves have been a common fodder for livestock, and needles have been used as bedding in stables. After the leaves were consumed, the branches were used for heating. Pollards were often situated in grazed land and a certain height was necessary to prevent grazing of the fresh branches. Cutting was repeated after some years when the new shoots had grown large enough. Repeated pollarding often creates peculiar shapes of trees, such as wide and low trunk with a multitude of branches from about the same place (Figure 3.4). Pollarding has also been common in parks, alleys and churchyards for ornamental reasons to create specific appearances of the trees.

Coppicing is repeated shoot harvest just as pollarding, but close to the ground (Figure 3.7). Coppicing could be done for leaf harvest in meadows and field margins, but was commonly repeated with longer intervals (several decades), with the primary goal to harvest wood of larger dimensions. Most deciduous forests of Europe have a history of coppice forestry, often called low forestry. Repeated coppicing creates elevated stools with multiple trunks visible long after pollarding ceases. Newly coppiced trees must be protected from grazing.

Figure 3.7a and b. Left Pollarded willow trees (*Salix* sp.) in an abandoned hay meadow in the county of Örebro, Sweden. Right: Coppiced ash tree (*Fraxinus excelsior*) in the edge of a former hay meadow in Uppland. Photo: Anna Westin.

Some trees carry traces of both pollarding and coppicing, showing that coppicing was replaced by pollarding for some reason, perhaps because the land was at some time needed for permanent grazing. Coppicing and pollarding both require light conditions for the trees to survive, thus their remnants are always indicators of light.

Cutting of hazel (*Corylus avellana*), and occasionally other tree species such as hornbeam, does not result in a stool, but rather new shoots from the ground beside the cut stem. As new shoots emerge and the old stems die, a ring of stems forms, whose diameter increases with age. An uncut hazel undergoes the same development, but the diameter of a repeatedly cut hazel grows much faster. The ring shape remains after coppicing has stopped, but in shady environments, parts of the ring may die, which makes it harder to detect.

Other kinds of damage

Trees may be damaged by grazing livestock, especially with high grazing pressure and winter grazing. Grazing of saplings prevents the forming of a single main stem; instead, a densely branched bush with multiple stems is formed. As grazing pressure releases (or when a shoot manages to grow above the grazing height) the tree grows as normal, but the former grazing impact remains visible as a zone of dense branching (most commonly seen on spruce and pine), or as trees with several stems (Figure 3.8).

Grazing may also damage the bark of tree trunks. Other causes of damage are, e.g., fire and intentional bark peeling for collecting bark or indicating paths or borders between landowners. Branches of trees have been cut for many everyday uses, such as covering of charcoal kilns and building floors for haystacks. Traces of cut branches often remain as long as the tree itself.

Figure 3.8a and b. Spruce trees can form several stems from high grazing pressure (left) and remain for a long time as BCH (right). Left photo is from the Rodna mountains in Romania, the right photo from the county of Dalarna, Sweden, Photo: Tommy Lennartsson.

Dendrochronology - Wood as a source of information in Historical Ecology

The stem of woody plants – trees, shrubs and rushes – grows radially by forming new cell layers just below the bark every growth season. In seasonal climates, cells produced in the early season have thinner walls than cells produced later in the season, and produce a ring of light wood, as compared to a darker ring of autumn wood. Living trees in seasonal climates can be aged directly through taking a wood core sample and counting the tree-rings.

Dead trees, stumps, and wood found in artefacts can be dated using a technique called dendrochronology. The method, developed in the early 20th century, is based on the fact that the width of tree-rings vary between years depending on the summer weather. Favourable weather gives higher growth rate and broader rings. Most trees in a region have experienced the same sequence of favourable and less favourable summers and their wood therefore show a similar series of broad and narrow rings. On living trees, exact years can be assigned to each ring, and series of ring-patterns can be dated. If the same pattern is found in a wood sample, all tree-rings of that sample can be dated. Dated samples may provide new conspicuous ring-patterns at earlier time periods, which can be matched with other samples, and so on (Miles 1997). Several overlapping series can be connected to a long continuous reference curve of growth ring patterns for a certain region. There are series stretching as far back as almost 14,000 years BP (van der Plecht et al. 2020). Such reference curves are important for calibrating radiocarbon (C-14) dating, but dendrochronology is in particular used for dating of time periods too recent for radiocarbon methods.

Dendrochronology is used in, for example, terrestrial and marine archaeology and history for dating artefacts, structures, and other wood that can be linked to human activities. Dating of the actual wood samples is very precise, but dating of the entire construction or context requires further interpretation by using other sources of information (e.g. Dillon et al. 2014; Edvardsson et al. 2021).

In Historical Ecology, tree-rings can be interpreted in many more ways than only for dating of wood samples. One is the dating of certain activities that have left scars or other traces in the wood. For example, the inner bark of Scots pine has been widely used as food among peoples in the north (Bergland 1992; Zackrisson et al. 2000). Dating of the blazes resulting from bark harvest has indicated that bark was harvested regularly by Saami people, not only as emergency food, and that the vanishing of bark peeling may be related to changes in reindeer herding (Niklasson et al. 1994).

Some tree species, such as Scots pine, survive forest fires, but each fire leaves fire scars in the trunk. Using dendrochronology, the scars can be dated also on dead trunks and stumps, in order to date fires and estimate fire frequencies and the geographic extent of single fires. By comparing found frequencies with known frequencies of lightning-initiated fires, human-induced fires can be detected and connected to, for example, periods of swidden agriculture or forest pasture burning (Niklasson & Karlsson 1997; Niklasson & Granström 2007).

Dendrochronology can tell when and at what age a tree of a certain tree species was logged in order to be used in construction material. Such information has been used to interpret the availability of forest resources, which may, in turn, be linked to the history of human forest use and other ecosystem changes (e.g. Grynaeus 2020), including the impact of climatic factors. Regarding climate, tree-rings are not only used for dating, but since ring width reflects tree growth rates, patterns of ring width may indicate patterns of climatic variation in the past (Esper et al. 2018).

These examples show how wood can be an important historical source material, not least for information about human use of natural resources. Knowledge about state, use, and variability of forests in the past is also of great importance in ecology and conservation biology. Today's biodiversity is always more or less a legacy of the past, and with better understanding of past conditions, we can better understand ecological processes and better preserve biodiversity by restoring former, more favourable conditions.

Methods of data collection and analysis

The knowledge foundation of BCH is Historical Ecology, which in turn rests on history and ecology, both in a broad sense. Ecological knowledge is necessary in order to identify species, understand their basic needs, how they react to different kinds of conditions (natural and anthropogenic), and to assess for how long the effect of the past can be traced. Historical knowledge is equally necessary in order to understand how people have altered their environment through their way of living, which specific activities have taken place, and the cultural background to these activities and to local communities' interactions with nature. A temporal aspect is present in both ecology and history since societal and ecological conditions have shifted with time.

The use of BCH is based on field work, where potentially human-shaped elements in nature are registered and interpreted in order to obtain information about human history. BCH tells us about the use of nature and natural resources, because such practices always leave traces in their ecosystems.

Since identifying and interpreting BCH is an interdisciplinary work, we are convinced that the most solid studies are made through collaboration between different scholars having well rooted knowledge in one field and a sincere interest in and curiosity about the other.

With ecological knowledge, species and communities of plants and animals can be identified and analyzed in order to understand, for example, links between a species and its environment, or why a tree or an ecosystem has its particular growth structure and biodiversity content. Through such understanding, observations in nature can be linked to certain sets of environmental conditions and processes, some of which have anthropogenic origin. Knowledge build-up is largely done by studying nature that is influenced by known current or recent human activities, sometimes comparing the observations with more pristine natural environments, relatively untouched by human activities.

Once a biological artifact or other human influence on nature is detected, historical information about past land use and other activities are used to interpret the field findings. There is relevant information found at different scales, from the different constituents of the regional land-use to the very local, in-farm practices. This information is found in, for example, primary sources such as maps, aerial photographs, written documents, interviews, or in publications which have already been summarized as land-use history. These are covered in individual chapters in this book.

Interpretation can often be assisted by using information from disciplinary fields other than ecology and history. Geology will inform about how bedrock and soil quality have shaped the possibilities and limitations for past land use, as well as for species, and how activities such as farming change the nutrient status of soils; geological maps are therefore a useful tool. Archaeology will inform about the long-term history and human settlement of the area. Registered cultural remains such as burial mounds, settlements, stone walls, and charcoal kilns give invaluable information about the extent, age and continuity of past human presence in the landscape. Ethnology and oral history can add more information about specific local practices, and such knowledge is often necessary for understanding what has formed the biological elements in question. Ethnological and anthropological information also tells us about the general cultural background relating to land use, e.g. cultural traditions and beliefs.

In practice, the methods for using BCH combine ecological and historical methods in a dialectic manner (Figure 3.10). Ecological observations and interpretations ask questions to history: what has happened here, and why? Historical information about human practices and natural resources asks questions to ecology: how were natural resources shaped, maintained and harvested from ecosystems, and how may such activities have left imprints in nature? Answers often generate new questions to both ecology and history.

Stepwise approach

We present here a brief model for how to work practically with BCH, based on what we have identified as the most important working steps in our own studies. We will also use the following scheme in the case studies later in this chapter. Of the following five steps, the first two are always done. The third may be done in order to widen the understanding of the historical background. Steps number four and five are optional and depend on the aim of the BCH inventory.

1. Identifying artifacts in nature
2. Interpreting the activity/activities that directly created the artifact
3. Interpreting the reasons behind the activity/activities
4. Assessing value for nature conservation and cultural heritage
5. Assessing needs for measures for preserving the BCH

Documentation is a key component in interpretation and contextualization. A thorough documentation of observations, questions, theories, sources used, as well as how the information in those have strengthened, weakened or developed new ideas. Together with photos and mapping, this type of documentation is priceless and can be developed as experience grows.

In the documentation it is important to differentiate between observation and interpretation. This makes it possible to return to the documentation and revise the interpretation. The shape of the old trees in figure 3.4 is an observation, while the notions that the shape is human made, as well as that it is the result of pollarding, are interpretations.

Figure 3.9. A tree with multiple trunks can be the result of natural wind damage, cutting of a trunk for recent forestry purposes, or of many years of coppicing (repeated cutting for wood and/or leaves). By learning how different types of damage produce different types of multi-stemmed trees, artifacts can be recognized in the field. Photo: Anna Westin.

Identifying artifacts in nature

The whole process starts with finding something in nature that is not purely natural. Often the investigator finds something that deviates from what is normal or expected in the ecosystem, such as the old trees in the dense young forest in Figure 3.6, or grassland plants in the forest, garden plants far from houses, or a tree with multiple trunks. The finding raises the questions about what caused the anomaly, and if the causes are natural or anthropogenic, i.e. a BCH. This is sometimes easy, sometimes more difficult (Figure 3.9).

Some biological features in nature are obviously a legacy of human activities, such as the old trees in figure 3.4, which have clearly been shaped by cutting. Other findings take some field experience to identify as BCH. Handbooks and other publications with examples of BCH are useful for developing an eye for artifacts in nature. If identification is uncertain, it may help to look for more occurrences of a structure or species; a single occurrence may be natural or by coincidence, but more of the same often indicates a land-use origin.

As mentioned, cultural influence is overlooked in many types of nature outside of pronounced cultural landscapes, and in order to discover BCH it is important not to be limited by “old truths” in ecology and history. For example, texts describing species' natural habitats rarely consider that the present habitats may be derived from historical habitats and management.

Activities creating the artifact - contextualisation begins

When something in nature has been identified as an artifact, it has a story to tell about human history, i.e. the context of its formation. In agricultural landscapes, a large proportion of BCH is formed by the most common activities, such as cutting of trees, cutting of branches, mowing, grazing and cultivation.

In the case of the old trees in figure 3.4, such trees are found throughout Europe, and we therefore know that they are formed by repeated cutting of new shoots, i.e. by pollarding. In practice, contextualisation is usually integrated with the identification, but as mentioned, it is wise to document observation and interpretation separately. Already when suspecting that a tree has been culturally shaped, there is probably an idea about what happened. If it is clear that a tree has been repeatedly cut, the activity has already been identified. But sometimes it is less obvious what created the artifact, and then it is appropriate to proceed, and finding more information about the land-use history is necessary.

Explaining activities - further contextualization

If we stay with the old trees in figure 3.4, we identified former pollarding in our first step of interpretation. We know, however, that pollarding may have been done for different purposes: for harvesting leaf fodder, firewood, charcoal burning, basket-making and so on. We deepen the interpretation in order to find the reasons behind the practices. These are investigated at two levels. Firstly, concerning the immediate reasons for the action, e.g. branches of a tree may have been cut to collect leaves, trees in a forest may have been cut to create more pasture, or grasses and herbs were mown in order to get hay for livestock. Secondly, concerning the wider context in which the activities and products used are situated. Information about the wider context will give a deeper understanding of the people and the socio-ecological conditions they acted within.

At this stage, if not before, it is necessary to consult other sources of information, as well as including additional BCH from the area in the interpretation. This is an exploratory phase where all kinds of information is put on the table in order to reveal new layers of knowledge. This is done in a dialectic manner between different sources (Figure 3.10). Starting with one initial question and alternative answers, each source is consulted for verification, falsification and creation of new ideas. Each source-consultation will generate clarifications or new questions that are brought back to the initial field findings, the artifact. Maybe there is more to find out about the artifact that develops the theory or questions, which initiates another consultation round with the other sources. This dialectical process continues until there is one or several plausible ideas. Sometimes no satisfactory interpretation will be reached, and that is also fine.

If we continue with the example of Romanian pollarded trees in figure 3.4, the shape of the pollards raises questions about what products were harvested by the pollarding, about the location of the pollards, the forest structure, and about the land use in general at the site. Historical maps together with oral information may suggest harvesting of leaf fodder from the trees together with grazing on the ground. We may also learn that leaves from beech were mainly used as fodder for sheep, as well as bedding in the stables.

The need for leaves as winter fodder can be linked to societal factors such as property rights and user rights, and to components of the former local agricultural system, such as the ratio between arable lands, meadows and pastures and the use of combined pasture-pollarding. The information about former grazing motivates a new field investigation, in order to find BCH from this practice. We may also look for BCH that can explain how the pasture was kept open. Also, the abandonment of both the pollarding and grazing has left traces in the ecosystem, in terms of young trees and oversized shoots on the pollards. Both can be dated and interpreted to tell about land-use changes and their causes.

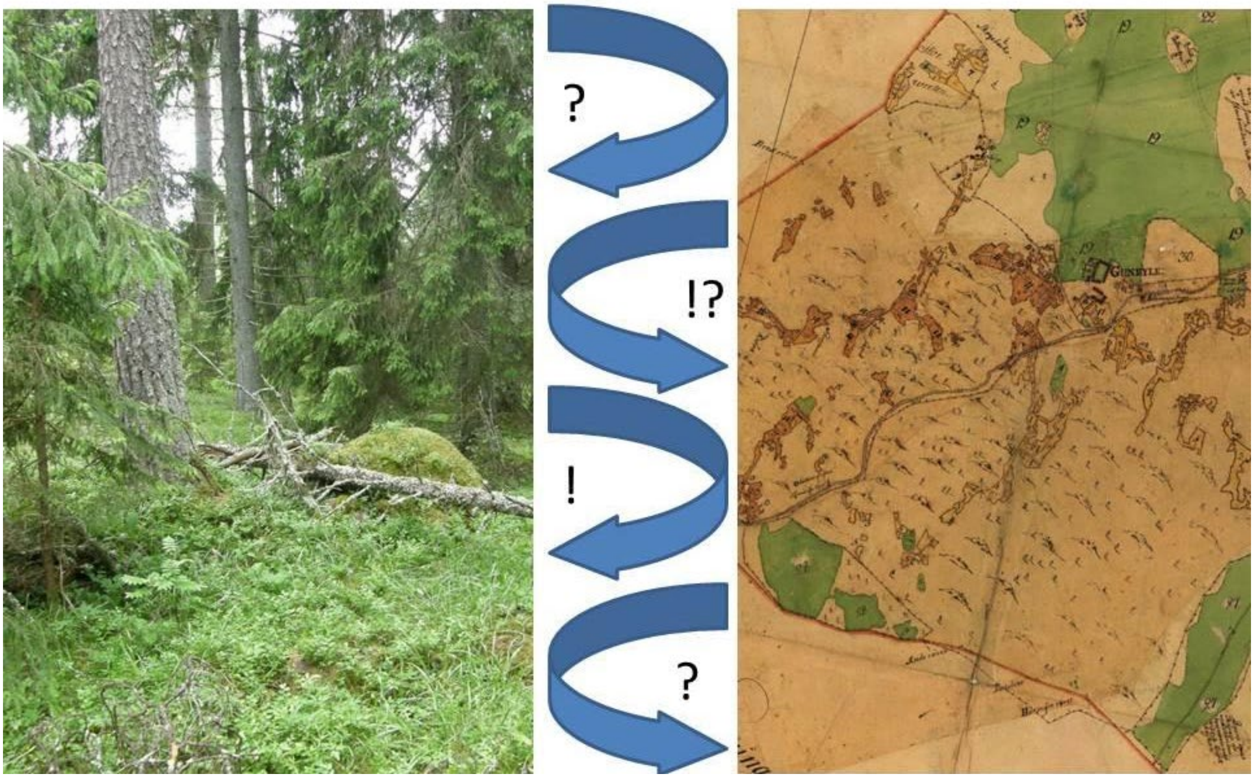


Figure 3.10. Illustration of the dialectic process of discovering the history of a biodiversity-rich forest in Uppland, Sweden. Field traces in the tree layer, the presence of vascular plants and mushrooms combined with historical information in cadastral maps and tax records, lead to the conclusion that the forest has been very much shaped by past grazing in combination with regular clearing for maintaining the forest's openness. Source: Section of historical map from 1753 over Gunbyle hamlet, Uppsala County in Sweden. Photo: Anna Westin.

Valuation and conservation

BCH is often associated with rich biodiversity. Traditional land uses have created species rich habitats, in particular various kinds of semi-natural grassland, which are now among the most threatened and valued types of habitats in Europe. The value of human-shaped habitats lies both in the importance for biodiversity and biodiversity conservation, and in the importance for cultural heritage, especially in terms of BCH.

Regarding values for cultural heritage, the richer the context, the more useful BCH becomes as a source to history and thus also as a heritage from our past. It may contribute with new knowledge about local or regional history that is not to be found in written or oral sources. In the field, BCH often contributes with information in areas that are scarce in other types of physical remnants, such as buildings, fences, and roads. BCH also brings us other types of information. For example, there may be stone fences or ditches surrounding a flat surface cleared of stones, which leads to the conclusion of an abandoned arable field. Remnants of vegetation may contribute with information about what was once cultivated. The understanding of BCH is to the landscape, what the small construction details and the authentic furniture are for historical houses.

There is a large overlap between BCH and the biodiversity of conservation. Since traditionally managed habitats are rapidly declining, their biodiversity (which constitutes a BCH) is threatened. Also other types of BCH, such as old culturally modified trees, are of great importance for biodiversity. But there are also many cases where biodiversity and heritage interests differ. Common species are not of concern for nature conservation but may still be an important heritage. On the other hand, some rare species may be of high concern for nature conservation but have weak, or no, historical indicator value.

Conservation of BCH differs from conservation of other heritage, since it is always changing. Old trees with traces of use, e.g. with cutting scars, will eventually die and decompose, even with the best of care. Old practices of tree management may have to be re-introduced and applied on younger trees to ensure regeneration of culturally modified trees and preserve the memory of the practice. Hence, the craftsmanship and practical understanding of traditional farming are key components of the BCH and its conservation (Chapter 10).

One of the most important links between BCH and biodiversity is that BCH can help us understand what has shaped the biodiversity we now try to preserve. The key to preservation is usually to restore former, more favourable conditions, but it is often difficult to find information about those conditions, i.e. to set up targets for restoration. Interpretation of BCH can provide new insights about former habitats and management regimes. For example, former pastures needing to be restored by resumed grazing. However, grazing can be designed in many different ways, and restoration often fails because of incorrect grazing. Successful species conservation may depend on details such as grazing pressure, the length of the grazing season, during which months grazing took place, possible rotation between different pastures, what types of livestock there were, and cover and details about trees and bushes. Understanding the history embedded in BCH is to understand what shaped biodiversity, which is a short-cut to finding successful conservation methods.

There is no systematic database for documenting BCH as far as we know. Heritage with close association with species or structures of conservation concern, may be part of different databases (ancient trees, high nature value grasslands etc.), which are usually set up only for biodiversity reasons. The historical context, which turns biodiversity into heritage, is not systematically recorded. Lack of systematic inventories and documentation is an important reason for ongoing loss of BCH. Documentation and building up the knowledge base on how to interpret BCH in different regional contexts, is therefore a very urgent task, and more people are needed for this task.

Sources

Below we list the most important sources and how they may be used to interpret BCH. Many of them are covered in detail in other chapters of this book.

Botanical literature

National and regional books on flora are of course crucial to identify plants at the species level, but they may also inform about what types of environments these are expected to be found. This is key information to interpret the species as sources (see above). It is important to remember that the information about environmental preference is usually based on current findings, thus they do not consider where they used to grow in the past, which is more interesting for a historical interpretation. Consultation of old botanic literature may therefore give more accurate information about past environments.

Regional and local literature

Literature describing the regional and local cultural history, in particular on how people made their livelihood and what kinds of activities that were involved in using the landscape, creates a valuable framework to the interpretation of field findings. Also, large natural events like forest fires and storms are important to consider, since they may create similar effects on forest structure as human deforestation.

Oral history, traditional knowledge, and indigenous and local knowledge

Interviewing elderly people from the local area may give important clues to what has happened in the area during their lifespan, such as the main livelihood and how it changed with time, storms, fires, draining projects etc. Local people may also know about unregistered heritage sites of importance for interpretation, such as charcoal kilns, former houses and roads. Farmers who have been working the land, may know interesting details about how grazing was organized, which meadows that were in use the longest, and what was cultivated in different places. People engaged in documenting local history and heritage may be a gold mine of information. They may even have access to unique photographs, farm tools, and documentary sources contributing with key information for interpretation of biological-historical heritage. Local experts can be engaged at different levels, from being only informants to full research participants engaged in interpretation and publication. These aspects are treated in chapter 10 on Engaged Historical Ecology.

Material culture

Fences, farm tools and other objects are interesting for two reasons. Firstly, because they give insights into important activities for which tools were needed. Secondly because the material that objects were made from say something about the local availability of resources. For example, wooden fences in Sweden were usually made from juniper and spruce. In forested regions, the number of fences added up to many kilometers and thousands of junipers were cut in the local forest. The amount of juniper needed for fencing is an indication of the openness of the forest, since they do not grow in the shade. The interpretation based on material culture must of course take into account whether there was a local tradition of buying different objects from other regions.

Historical photographs

Photos from the early 20th century onwards may show people, tools, livestock, landscapes and activities. Commonly, photos were taken by the house, with people and livestock looking their best. But pictures may also have been taken elsewhere in the landscape showing e.g. vegetation and trees (see also chapter 2).

Reference landscapes

In countries where the traditional land use has been gone for a long time, key information may be missing simply because the landscapes and land uses have changed, and no source has documented what went lost. Visiting areas where traditional land uses are still vivid, may give new ideas vital for the interpretation. These reference landscapes may be situated in the same country or abroad. As Swedish land-use researchers, the authors have visited the Romanian countryside many times with fruitful contributions to the interpretation of the Swedish landscape and historical sources. Although the socio-economic conditions may be very different, the two countries show large resemblances in basic ecosystem use, traditional land use methods and species pools. For example, grassland species that are rare in Sweden because land use and landscapes have changed, may still be common in Romania. The study of populations in a good state and in a land-use type that favors them, is invaluable to understanding the history of their habitats.

Reference landscapes are preferably studied by combining field observations, interviews, and historical sources, in collaboration with local experts.

Other sources

- Documentary sources (Chapter 2)
- Cadastral maps and other land use maps (Chapter 6)

- Economic maps (Chapter 6)
- Aerial photographs (Chapter 12)
- Archaeology (Chapter 8)

Field techniques, data collection, tools, and software

Being a new field, there is not really an established method on how to perform BCH field work. We find it useful to bring all available historical maps, georeferenced in a field tablet. This makes orientation in the historical landscape easier. We also consult different map applications based on available online databases with registered archaeological findings, protected areas, terrain, and satellite images.

Field information is collected as waypoints, linear objects, or surfaces, which can be implemented into a GIS map. There are different software applications, but so far we have used Avenza maps in the field, and QGIS for data processing (Chapter 11).

Any type of relevant information is collected: individual species, culturally shaped trees, bushes, remnants of fences, houses, industrial activities, ditches, roads, quarries and much more. More complex information, such as long species lists, are collected in worksheets and correlated to a waypoint.

Depending on the type of data collected, it is analyzed qualitatively or quantitatively, in which case we use common statistical programs or GIS. We often combine different tools and software in a project, which is determined by the type of data collected.

Examples from our research projects and study areas

Pilot study 1. Summer farms in Bruksvallarna, Sweden

Wooded pastures were of great importance and have covered large areas in pre-industrial Sweden. Despite this, the knowledge about them is very limited. In a project about near-alpine forests, we made a pilot study about a forest in a summer farming area of Bruksvallarna in the county of Jämtland, Sweden (Lennartsson et al. 2023). We mapped BCH within two hectares of formerly grazed forest. In the interpretation we also used a cadastral map from 1889 and interviews with summer farmers born in the 1940's and 1950's.

The forests west of river Ljusnan in Bruksvallarna have a long history as a summer farm area. As recently as the 1950's, there was full activity with animals, grazing, mowing and milk handling, after which summer farming ceased and changed. Today, a few active summer farms remain, where the character of grazing and biological diversity is preserved. The greater part of the area contains only remnants of the summer farm houses and their surrounding former fields, while the old forest pastures give a highly natural impression, varied with old trees, mires and standing and lying dead wood (Figure 3.11).

Figure 3.11. A formerly grazed forest in the summer farming area in Bruksvallarna, Sweden. Photo: Tommy Lennartsson.

Figure 3.12. Multi-stemmed birch elevated on a stool resulting from repeated cutting, probably for firewood needed to prepare cheese at the summer farm. Photo: Tommy Lennartsson.

But at a closer look, the seemingly natural forest landscape is loaded with BCH (Figure 3.14). The most common types of heritage are culturally modified birches (Figure 3.12) and spruces (Figure 3.8) and ground vegetation. We recorded 71 multi-stemmed birches, some of which are elevated as a stool. There are 36 old spruce trees with traces of grazing damage, either as multi-stemmed or with a thick brush of dead branches low on the trunk. There is also a multi-stemmed rowan, and some old juniper bushes. About 20% of the surface has a richer vascular plant flora with species that belong to grazed or mown vegetation types.

In 1889, the nearest summer farming houses were situated only 250 meters from the investigated area, as shown by cadastral maps and remaining houses (Figure 3.13). Most of the area was by the surveyor termed as "birch land", but also "birch and pasture land", and various terms for wetlands used for mowing. It is clear that this forest was a place for intensive grazing and other land uses in the late 19th century. Indeed, as late as in the 1950s, goat keeping was increasing in order to satisfy the tourists' desire to buy goat cheese.

In figure 3.14 we differentiate between observation and interpretation. According to our conclusions, spruces with multiple trunks have been shaped by intense goat grazing. Also, the birches could have been shaped by grazing, but our interpretation is that they were coppiced to get firewood for processing the milk. “Birch land” in the map indicates that birch was an important resource. Grazing and coppicing keeps a forest open and light, also shown by light demanding junipers.

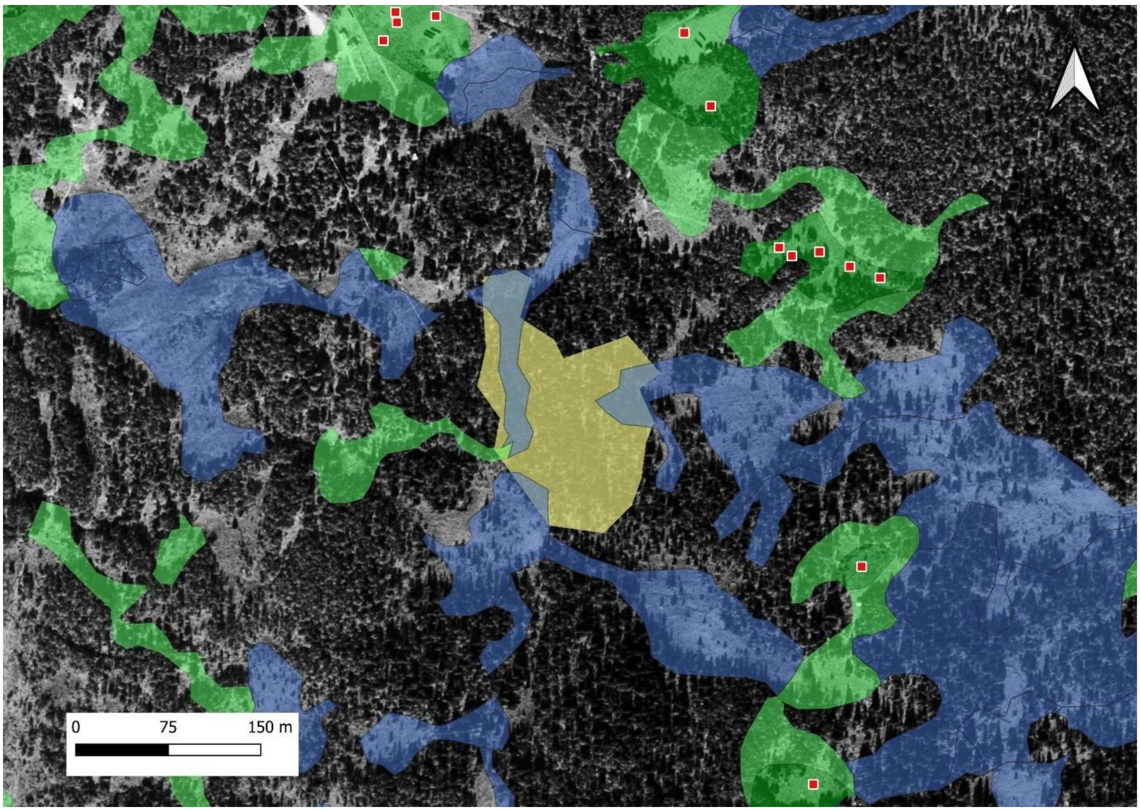


Figure 3.13. Studied area (yellow) against the background of an aerial photograph from the 1960s. Other information comes from a cadastral map from 1889: the red markings show houses, green areas are dry hay meadows, blue areas are wet meadows. Other land was various types of forest, pasture, slopes and rivers. Sources: Laga skifte Funäsdalen Malmagen etc. 1887. Lantmäteristyrelsens arkiv Y56-7:1, Historical orthophoto with reference year 1966, Lantmäteriet open geodata.

The mires, swampy or boggy ground, were mown to get hay as winter fodder. Informants have told us that hay was stored in stacks to keep it dry until the hay could be transported to the farm in winter, taking advantage of the snow and ice for making convenient transport roads through the forest. We found two places where materials for constructing stacks were stored. These were placed under a large spruce tree on dryer land, indicating where the stacks had been built.

We also found traces of birch bark peeling, scars in trees from harvest of material for handicraft, and traces of branch harvest on spruces. The use of branches is not clear to us, but they could have been used as “floors” under the haystacks, or as simple fences to protect stacks from grazing animals, among other possible uses.

The three main sources: cadastral maps, oral information, and BCH, testify in unison about a historically intensively used landscape. They inform us about different time periods and provide different kinds of information. The information provides answers about land use but also raises new questions.

The informants' memories stretch as far back as to the 1950s, when goat farming was vivid and mowing was still taking place around the summer farms and in mires. They informed us about the approximate number of goats, sheep and cows at each summer farm, and about the forest structure: ‘the forest was grazed and open and looked like a park’.

The terms in the cadastral maps raise questions as to what a "birch land", "pasture land" etc. actually looked like and how it was used. A deeper field investigation could be of help, e.g. through a careful and comprehensive mapping of BCH in various sub-areas.

The mowed wetlands raise questions about what the managed vegetation actually looked like, and which species and vegetation types remain from the mown state.

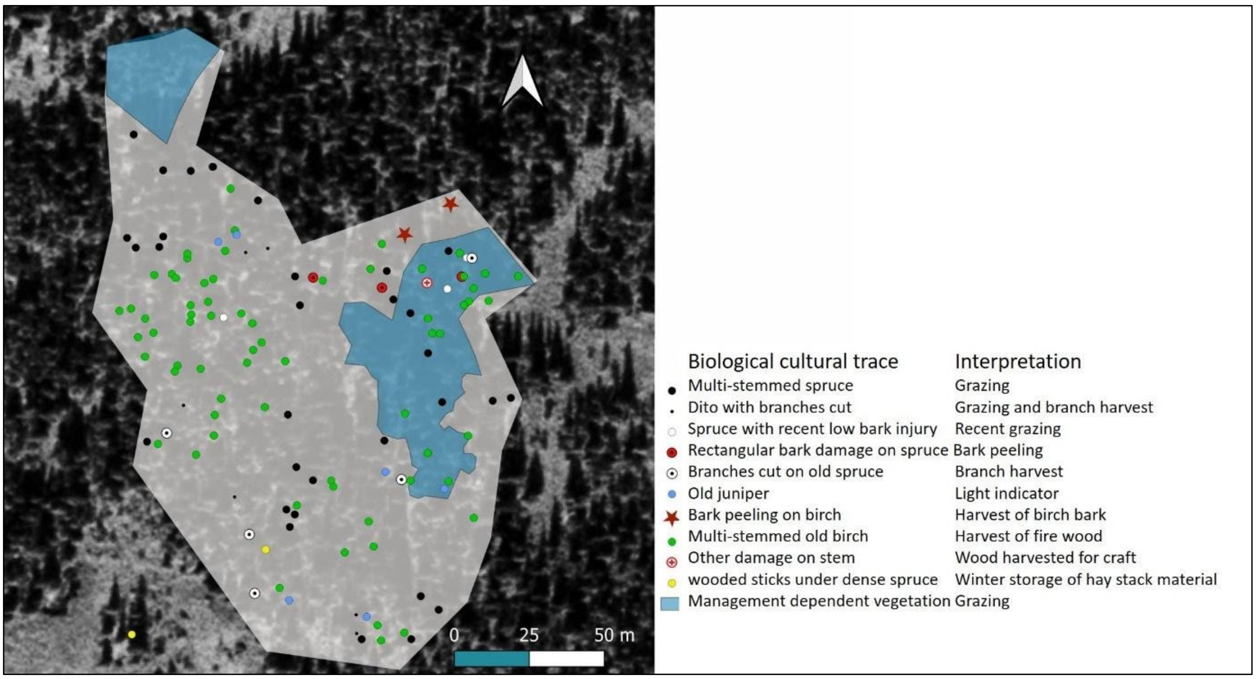


Figure 3.14. Mapped biological cultural heritage in a near-alpine forest in Sweden. Illustration: Anna Westin.

Figure 3.15. The cowslip grows to the right of the old stone fence, but not to the left. Even further to the left, a modern fence defines the border to a forest pasture.

Pilot study 2. Past grazing regimes imprinted in the flora

On Brottö island in the archipelago of the Swedish Baltic, the herb cowslip (*Primula veris*) grows between an arable field and a stone fence, but not at all on the other side of the stone fence (Figure 3.15). Why is that, and what can the history of this cowslip population teach us about the past?

First, the cowslip is confined to grassland, which in this region is always a human-made habitat. The occurrence of the species is therefore an artifact, a BCH. The soil and other conditions are similar on both sides of the fence, and it is therefore likely that also the peculiar distribution with presence on one side and absence from the other, has anthropogenic origin. We begin the interpretation by examining the land use history using a cadastral map from 1859 (Figure 3.16.).

Most of this part of the island was pasture, possibly for grazing during the entire summer. A fence around the fields kept the crops safe from grazing livestock until after harvest, when they were let in to graze arable fields as well as the edges around fields. The place where the cowslip grows today has thus, historically, not been grazed until very late in summer, perhaps in mid-August or even later, depending on what was cultivated in the field. The cowslip thus grows where late grazing was practised, but is missing left of the stone fence, which was subject to grazing all summer. Is the distribution of the cowslip explained by historical grazing timing?

Looking closer into the ecology of the cowslip, we see that it is indeed one of many early flowering species that benefit from late management, which allows it to flower and set mature seeds before grazing or mowing starts. Consequently, it is common to find cowslip on pastures and hay meadows that have traditionally had late management. This pattern can sometimes, as in this case, persist after the late management has ceased, which makes cowslip a BCH from grasslands with late management.

Today the fence is situated a few meters away from the arable field, which means that both sides of the old stone wall are grazed in the same way. In the long run this will erase the difference between both sides of the stone fence, and thus the land-use memory shown by cowslip will disappear. In order to preserve the current pattern, it is desirable to relocate the fence to its former position and return to the former grazing regime. Preserving cowslip will also benefit a set of other plant species and insects that are favored by late onset of grazing.

Figure 3.16. Historic fencing system on the western part of the island of Brottö, in Stockholm County in 1852. Arable fields have been colored red and fences are black. The yellow arrow shows where the photo in figure 3.15 was taken. Source: Laga skifte 1852, Lantmäterimyndigheternas arkiv 01-lju-56.

Examples from other disciplinary and interdisciplinary projects

The biological cultural imprints in forests around Europe have been studied by several research groups, some of which have summarised their findings in a book edited by Bürgi et al. (2020). Six case studies are presented and discussed in the book in the light of how the biodiversity of the forest has been influenced by traditional use and how the knowledge of these traditions can help sustaining this diversity. The first case is from the border between Hungary and Ukraine and exemplifies how land use during the late 20th century influences how much of BCH remains. On both sides of the border, the oak forest was used for pannage, the right or privilege of feeding pigs or other animals in a forest. This tradition has been sustained in Hungary, along with a varied forest, whereas in Soviet Ukraine, forestry was intensified, leading to homogenisation of the forest. The second case describes how a palette of historical land uses has created diversity in ecosystems. In the otherwise intensely used landscape east of Prague, land use has changed over time into new types of land uses. Examples range from Baroque designed parks, over broad-leaved forests, coppices, to orchards. The third case describes how a dynamic land-use history has created much of the observed diverse forest patterns in almost 3000 forest key habitats in Zemgale, Latvia. Iron manufacturing activities, including medium-intense logging during the eighteenth century, was a key factor for creating diverse forest patterns. In case four, the researchers advocate for recreating the historical mosaic of Mediterranean grazed landscape in Catalonia, Spain, because today's habitats encroached by forest on cropland and pastureland, hold low-quality forests, very prone to wildfires. Another case summarizes years of research into the intensively used forests in the Italian Apennines. Among other things, the significance of white alder (*Alnus incana*) for sustaining the local agricultural system is emphasized. The conclusion of the study is that the intricate relationship between the forests and the locally adapted uses of them have created forests which are not just highly biodiverse ecosystems, but equally important as cultural legacies of distant and recent past.

Figure 3.17. Saami bark peeling in Muddus, Lappland. Photo: Tommy Lennartsson.

The final case is from northern Swedish Sápmi, where there is a general idea of the untouched forest landscape, despite Sami landscape use dating back millennia. This research group has documented and analyzed biological cultural traces to prove the Sami use of the landscape. An important task has been to document culturally marked trees, CMT, (e.g. Östlund et al. 2003). Sami people traditionally lived on a combination of milk reindeer herding, hunting, fishing, and collecting plants. One important food source was the inner bark of Scots pine (Pinus sylvestris) which was used as food among other things. The inner bark was collected by peeling off the outer bark and left permanent scars in the trees (Figure 3.17). Anna-Maria Rutio et al. (2014) studied bark-peelings to assess the magnitude and spatiotemporal patterns of inner bark in a nature reserve in the northernmost Sweden. They also recorded archaeological traces, hearths (fireplaces) and storage platforms. There was a concentration of recorded objects close to a lake. Dendrochronological dating of the scars enabled the group to establish that the same site had been used nearly every decade from the late 16th to late 19th century, but with a varying frequency. The fact that the harvest levels were low in comparison to other studies lead the authors to the conclusion that the inner bark was primarily used in spring as a supplementary health food, when the availability of other food sources such as game meat, was low.

Limitations and benefits of working with BCH

The main benefit of working with BCH is that it represents manifestations of Historical Ecology, it gives insight into people's relationships with nature, and it provides direct keys to conservation. The methods used bring together different disciplines (history and biology, both in a broad sense), and make a meeting point for nature and cultural heritage conservation. The combination of sources and the interface between history and biology also brings new knowledge and perspective to both disciplines. The fact that many sources, disciplines, and techniques are used may feel overwhelming but makes an excellent field for rewarding collaboration.

Best practices and sources of errors and problems

Working with BCH is based on a constant exploration of nature, culture, sources, methods, software and publications. We have summarized the most important aspects to keep in mind to make the exploration as fruitful as possible:

- Transparency and documentation. Be clear on what kind of information that was used and differentiate between observation and interpretation.
- Develop a good ecological reference. With increasing field experience, it is possible to develop a good knowledge base on what is common/expected and what is rare/unexpected. This helps finding and interpreting BCH.
- Dialogue between different sources. Stepwise interpretation where questions are alternating between the different sources, each bringing new answers and questions to continue with.
- Consider time. Reflect on how long different traces may remain in trees, vegetation, etc. How does dating of BCH correspond with time reflected in other sources? Are there several shifts in land use that may be traced in the landscape?
- Consider space. BCH can be stationary, such as trees, telling about the environment on the spot. Other BCH is mobile, such as vascular plants and insects, and indicate conditions in a wider area and not necessarily where they appear at present.

- Consider different layers of vegetation. Trees, shrubs, herb-grass, and ground level vegetation complement each other with information of past times. They also influence each other. For example, shrubs can only survive where there is enough light, i.e. not too dense forest.
- Source criticism. Both historical sources and ecological knowledge about species should be used with sound skepticism and source criticism. Most biologists lack in-depth historical knowledge, and the general knowledge about species may need to be refined when seen in a historical context. Most historians lack in-depth biological knowledge, and historical sources have rarely been interpreted in ecological contexts.
- Interdisciplinary collaboration. The most fruitful way to work with BCH is to work together with experts of other disciplines.
- Every study of BCH is pioneering work. Compared to many other methods, there is still much to learn and to develop.

Sources of data, copyright and privacy issues, sharing and explaining data to others

Different countries have different regulations and policies concerning how freely you are allowed to walk in nature on common and private land. Even where allowed, landowners usually appreciate being contacted in advance if a field survey is performed. That also gives a chance to explain what the study is about and spread the word on what BCH is. Landowners' engagement may also contribute with important oral information. Publishing of any personal information, or data from interviews must be approved by the informants and undergo appropriate approval processes. Questions on permission should be raised before the interview starts, in order to avoid misunderstandings. The informants must have the chance to read and correct the information used. The permission form should include complete information about the publication, for example the type of media, spreading and copyright.

The copyright of other kinds of sources must be looked into separately as there may be differences between different countries.

Cost and effort required, training needed

At present, few universities offer interdisciplinary training, such as the combination of history and ecology. Therefore, the interest in BCH is usually founded in personal interest or emanating from questions needing interdisciplinary approaches. One such basis of interest is nature conservation in cultural landscapes.

Working with BCH is a craft that requires time for getting skilled. As mentioned, one important key is to work in collaboration with other disciplines, but with time, one person can also develop good skills.

Existing guidebooks, field guides, and tutorials

Looking at the entire range of BCH: from identification, interpretation, conservation, to application in different types of landscapes, the practical literature is very unevenly spread.

We have the impression that there is much literature (national and international) on cultural landscapes, especially grasslands and ancient trees in semi-open landscapes, that acknowledge that they are cultural remnants that need specific measures to be preserved. In contrast, the literature on forests usually focuses on the natural. We have found that tutorials on interpretation are largely missing, meaning that the value of BCH as a historical source is much under-used. We have also found that when examining the detailed history of an artifact in nature it often leads to the conclusions that routine management advice is not sufficient to preserve neither biodiversity nor heritage values.

The chapter authors have written a number of guidebooks on e.g. identification, interpretation, documentation and compiling knowledge on BCH in different types of habitats/land use types (e.g. Lennartsson 2913, 2016, Westin 2014, Ljung et al. 2015), financed by the Swedish heritage board and the Swedish Environmental Protection Agency.

Conclusions

Although the roots of biological cultural heritage are deep, the methods on how to work with interpretation in detail are very young. There is much more to be done in this exciting field of knowledge. But the clock is ticking fast. Memories of the landscape mediated by living organisms are eroding as trees are being cut and grasslands are abandoned or cultivated. For anyone interested there is much to learn and to do and there is a good chance that the knowledge derived can make a difference if communicated with landowners and officials in charge of restoration and management of nature.

References

Bergland, E. O. (1992). Historic period Plateau Culture tree peeling in the western Cascades of Oregon. Northwest Anthropological Research Notes 25: 31–53.

Berkes, F., & Folke, C. (1998). Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press, New York.

Bürgi, M., Cevasco, R., Demeter, L., Fescenko, A., Gabellieri, N., Marull, J., Östlund, L., Šantrůčková, M., & Wohlgemuth, T. (2020). Where do we come from? Cultural heritage in forests and forest management. In F. Krumm, A. Schuck, & A. Rigling (Eds.), How to balance forestry and biodiversity conservation – A view across Europe (pp. 47-61). Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf.

Crumley, C., Lennartsson, T., & Westin, A. (Eds.). (2018). Issues and Concepts in Historical Ecology - The Past and Future of Landscapes and Regions. Cambridge University Press.

Dillon, C., Bell, N., Fouseki, K., Laurenson, P., Thompson, A. & Strlič, M. (2014). Mind the gap: Rigour and relevance in collaborative heritage science research. Heritage Science 2, article 11.

Edvardsson, J., Almevik, G., Lindblad, L., Linderson, H. & Melin, K.-M. (2021). How cultural heritage studies based on dendrochronology can be improved through two-way communication. Forests 12: 1047, https://doi.org/10.3390/f12081047.

Eriksson, O. (2018). What is biological cultural heritage and why should we care about it? An example from Swedish rural landscapes and forests. Nature Conservation, 28, 1–32. http://dx.doi.org/10.3897/natureconservatio.n.28.25067.

Esper, J., St. George, S., Anchukaitis, K., D'Arrigo, R., Ljungqvist, F.C., Luterbacher, J., Schneider, L., Stoffel, M., Wilson, R. & Büntgen, U. (2018). Large-scale, millennial-length temperature reconstructions from tree-rings. Dendrochronologia 50: 81–90.

Fischer-Kowalski, M., Reenberg, A., Schaffartzik, A., & Mayer, A. (2014). Ester Boserup's Legacy on Sustainability : Orientations for Contemporary Research. Springer

Frödin, J. (1952). Skogar och myrar i norra Sverige, i deras funktioner som betesmark och slåtter. Inst. Sammenl. Kulturforskning, Oslo.

Frödin, J. (1954). Uppländska betes- och slåttermarker i gamla tider. Deras utnyttjande genom landskapets fäbodväsen. Geographica 29, Uppsala.

Gavin, M. C., McCarter, J., Mead, A., Berkes, F., Stepp, J. R., Peterson, D., & Tang, R. (2015) Defining Biocultural Approaches to Conservation. Trends in Ecology and Evolution, 30(3), 140–145. https://doi.org/10.1016/j.tree.2014.12.005

Grynaeus, A. (2020). Dendrochronology and environmental history: The difficulties of interpretation. The Hungarian Historical Review 9: 302-314.

Gustavsson, E., Lennartsson, T., & Emanuelsson, M. (2007). Land use more than 200 years ago explains current grassland plant diversity in a Swedish agricultural landscape. Biological conservation, 138, 47-59.

Lennartsson, T. (2013). Träd och buskar, månghundraåriga historieberättare. Riksantikvarieämbetet.

Lennartsson, T. (2016). Växter och vegetation som biologiskt kulturarv. Riksantikvarieämbetet.

Lennartsson, T., Tunón, H., Westin, A., & Ljung, T. (2023). Kulturprägel i fjällnära skog. Riksantikvarieämbetet

Lindbladh, M., Fraver, S., Edvardsson, J. & Felton, A. (2013). Past forest composition, structures and processes—How paleoecology can contribute to forest conservation. Biological Conservation 168: 116–127.

Lindholm, K.-J., & Ekblom, A. (2019). A framework for exploring and managing biocultural heritage. Anthropocene, 25, 100195. http://dx.doi.org/10.1016/j.ancene.2019.100195

Ljung, T., Lennartsson, T., & Westin, A. (2015). Inventering av biologiskt kulturarv. Riksantikvarieämbetet.

Maffi, L. & Woodley, E. (2010). Biocultural diversity conservation, a global sourcebook. Earthscan, New York.

Miles, D. (1997). The interpretation, presentation and use of tree-ring dates. Vernacular Archaeology 28: 40–56.

Niklasson, M. & Granström, A. (2000). Number and sizes of fires: Longterm spatially explicit fire history in a Swedish boreal landsscape. Ecology 81:1484–1499.

Niklasson, M. & Karlsson, M. (1997). Brandhistorik i Murstensdalen. Rapport 1997:1. Länsstyrelsen i Örebro län, Örebro.

Niklasson, M., Zachrisson, O. & Östlund, L. (1994). A dendroecological reconstruction of use by Saami of Scots Pine (Pinus sylvestris L.) inner bark over the last 350 years at Sädvajaure, N. Sweden. Vegetation History and Archaeobotany 3: 183-190.

Rackham, O. (2003). Ancient Woodland: its history, vegetation and uses in England (New ed.). Castlepoint Press.

Rautio, A.-M., Josefsson, T., & Östlund, L. (2014). Sami Resource Utilization and Site Selection: Historical Harvesting of Inner Bark in Northern Sweden. Human Ecology, 42,137–146. https://doi.org/10.1007/s10745-013-9624-6

Roberta, C. (2010). Environmental heritage of a past cultural landscape : Alder woods in the upper aveto valley of the northwestern Apennines. In M. Armiero & M. Hall (Eds.), Nature and History in Modern Italy. (pp. 126-140). Ohio University Press.

Rotherham, I. D. (2007). The implications of perceptions and cultural knowledge loss for the management of wooded landscapes: A UK case-study. Forest Ecology and Management, 249, 100–115. https://doi.org/10.1016/j.foreco.2007.05.030 Östlund, L., Ericsson, T. S., Zackrisson, O., & Andersson, R. (2003). Traces of past sami forest use: An ecological study of culturally modifed trees and earlier land use within a boreal forest reserve. Scandinavian Journal of Forest Research 18,78–89. https://doi.org/10.1080/02827581.2003.10383140

Swedish National Heritage Board. (2020). Biologiskt kulturarv: växande historia.

Swiderska, K. (2020) Biocultural Heritage Territories: Key to Halting Biodiversity Loss. Biodiversity Briefing, July 2020. http://pubs.iied.org/17760IIED

Van der Plecht, J., Bronck Ramsey, C., Heaton, T.J., Scott, E.M. & Talamo, S. (2020). Recent developments in calibration for archaeological and environmental samples. Radiocarbon 62: 1095–1117.

Westin, A. (2014). Att tyda landskapets berättelser - En metod att tolka biologiskt kulturarv. Riksantikvarieämbetet.

Zackrisson, O., Östlund, L., Korhonen, O. & Bergman, I. (2000). The ancient use of Pinus sylvestris L. (Scots pine) inner bark by Sami people in northern Sweden, related to cultural and ecological factors. Vegetation History and Archaeobotany 9: 99–109.

CHAPTER 4

PALEOECOLOGY

PER LAGERÅS

Paleoecology is the scientific study of environmental conditions and ecological relationships in the past. The source material is usually fossils. It may be petrified wood, shells, or even dinosaur bones from millions of years ago, but also includes much more recent remains. Of most interest to Historical Ecology is Holocene palaeoecology, which focuses on the period from after the last ice age to the present. From this geologically very recent period, plant and animal remains are rarely fossilized in the meaning of being petrified. They are referred to as subfossils and can be found, for example, in peat and mud layers. Due to the short time depth, Holocene palaeoecology deals with the same species that exist today, and therefore provides a very important historical background to today's ecological conditions. Also, and most importantly for the scope of this book, it deals with the period when humans in many parts of the world went from hunters to farmers and gradually exerted an increasingly severe pressure on the environment. Palaeoecology is therefore an important tool also in the study of human history, particularly human-environment interactions.

Palaeoecology, like ecology, involves plants, animals, and the environment. Here, however, we focus on the study of plant remains and what it can contribute to Historical Ecology. Even though palaeoecology is often applied to prehistoric periods from which there are no written sources, it can make important contributions also to the more recent periods that dominate within Historical Ecology, and even for periods and places from which we have written records and other historical sources.

Plant palaeoecology is the analysis of physical remains of the actual plants. Above all, two types of plant remains are important, namely macrofossils (seeds, fruits, etc.) and pollen. Fascinatingly enough, such small and sensitive plant remains can be preserved in the ground and may be identified even after thousands of years, if the preservation conditions are right. Why macrofossils and pollen have gained so much attention is because they are better preserved than most other plant parts, and that they have characteristic appearances that enable identification to plant species, genus, or family.

Palaeoecological records may be very species rich, and they may include different plants when compared to other historical sources. While written documents and maps usually only deal with economically important plants - mainly cultivated plants but sometimes also wild plants if they had economic value - the palaeoecological archive contains a much wider spectrum of plants. The cultivated plants are usually included, but also plants that are rarely mentioned in the historical records, such as arable weeds, ruderals, plants of meadows and pasture, wetland plants, trees and shrubs, etc. Therefore, palaeoecology can make important contributions to the study of past ecological conditions and of agrarian systems and their sustainability.

In this chapter I explain the two most important techniques in plant palaeoecology: pollen analysis and macrofossil analysis. I also present two case studies that exemplify how these techniques can be used to study past human interaction with the environment.

Figure 4.1. Plant-macrofossils retrieved from a well in Fjelie Village, southern Sweden. The well was radiocarbon dated to cal. AD 1420–1620. The photo shows one charred barley grain and numerous uncharred seeds of useful plants (hops, henbane, elder, etc.), weeds, and ruderals. Photo: Per Lagerås.

Pollen and plant macrofossils

Pollen grains are microscopic, often only a few hundredths of a millimetre across. They spread during flowering with the purpose to fertilise female flowers in sexual reproduction. To do this, different species use different strategies. Insect-pollinated species (often those with colourful and fragrant flowers) attract insects to make them carry the pollen grains from flower to flower. This type of pollen dispersal has a high hit rate, that is, a large part of the pollen produced reaches its target. Wind-pollinated plants (these have anonymous flowers, such as grasses and many trees) use a different strategy, and simply release large amounts of pollen in the air and hope that some will reach female flowers. As can be understood, the spill is very large from the latter group, and that is why pollen from wind-pollinated species dominates our soil samples. Because pollen grains are so small and light, and are effectively mixed in the air, pollen samples are good for providing a picture of the surrounding vegetation.

Each pollen sample reflects the vegetation at the time of its deposition. By analysing the pollen composition of samples in a stratigraphic sequence, it is possible to study how vegetation in an area has changed over time.

Peat and mud sequences from peatlands and lakes, with their pollen content, are therefore invaluable historical archives. Such sequences can be used to study vegetation development over thousands of years.

Plant macrofossils is a collective term for seeds and other larger non-microscopic plant remains (macro in this connection means that they are visible to the naked eye). Seeds in flowering plants are the result of sexual fertilisation and their function is to fall to the ground and germinate into a new plant. They are significantly larger than pollen grains, often from a few tenth of a millimetre to several centimetres, and therefore do not spread nearly as far (Figure 4.1). Some seeds may be carried longer distances by wind, or by birds and other animals, but the vast majority are transported only a few metres. Seeds and other macrofossils in a soil sample are therefore generally more local than the pollen content, and samples taken only a few metres apart may have completely different macrofossil compositions. An interesting thing about seeds and other macrobotanical remains is that they are sometimes themselves the sought-after, edible, and used part of plants (cereal grains, flaxseeds, buckwheat, berries, nuts, and many more), which humans have stored, processed, traded, and eaten. Seeds found in the remains of an abandoned house, for example, may not only show that a particular plant species grew in the area, but also that it was harvested or collected, and processed in the household.

Figure 4.2. Peat and lake-mud sequences, with their content of pollen and macrofossils, are nature's own historical archives. Core from a peatland in southern Sweden. Photo: Per Lagerås.

Where to take samples

Pollen is mainly preserved in wet, oxygen-free environments, like lake-sediment stratigraphies, and peat deposits. Such sequences can be sampled with simple coring equipment (Figure 4.2). Because pollen is transported far by the wind, samples from wetlands also reflect the vegetation on dry land surrounding the wetland, often within a radius of a few kilometres. The precise length of this radius is not possible to calculate, mainly because pollen grains of different species fly different distances, but it can be estimated based on the lake radius (Sugita 1994). A rule of thumb is that the larger the lake, the larger the pollen source area. Therefore, to make a local study, one can preferably take samples in a small peatland or very small lake.

During archaeological investigations of settlements, the remains of ancient wells are sometimes found and excavated (Figure 4.5). The water-logged sediments in such wells have good pollen preservation and can provide a picture of the local vegetation and land use in and around the investigated settlement.

Although pollen samples are preferably taken in wet environments, in some cases pollen can also be preserved in dry soil, especially if the soil pH is low. In this way, samples from, for example, clearance cairns and fossil arable fields may be analysed. Pollen preservation in such dry soil is often poor but may still be sufficient to provide a glimpse of past cultivation and environment.

Like pollen, also seeds and other macrofossils are well preserved in wet sediments. But unlike pollen grains, most seeds can be preserved (and identified) also as charred. This makes macrofossil analysis particularly useful in archaeology. In settlements where domestic fires have been used, cereal grains and other macroscopic plant remains have often been (unintentionally) charred. This charring makes the plant remains resistant to biological decomposition and charred grains and seeds (and of course charcoal) can be preserved for thousands of years in ordinary dry soil. Samples taken at archaeological excavations usually contain plenty of carbonized macrofossils. Most common are cereals, arable weeds, and ruderals. Seeds from meadow and pasture plants are less common, probably because hay fodder was kept away from fire, but may show up in large numbers in some contexts.

Microscoping and plant identification

Samples for pollen analysis are chemically treated with various acids to concentrate the pollen grains before analysis. The analysis itself is performed using a light microscope, often with 400–1000 times magnification. Phase contrast is helpful for identification. To obtain a statistically good result, approximately one thousand pollen grains should be identified in each sample. This is rarely a problem, as lake mud and peat can contain hundreds of thousands of pollen grains per cubic centimetre. For the determination of pollen grains, there are published identification keys (Beug 2004; Moore et al. 1991). A reference collection of recent pollen grains is also a good aid. Sometimes it is possible to identify pollen grains to species level, but often only to genus, and sometimes only to family.

Samples for macrofossil analysis do not need to be chemically treated. To retrieve carbonized macrofossils from dry soil, flotation is used. This means that the sample is poured into water, whereby the charred material floats up and can be collected with a net (Figure 4.3). The analysis is carried out using a low magnification microscope, often with approximately 5-50 times magnification, and reflective light. Here, too, there are identification keys and photo guides (Cappers et al. 2006; Neef, Cappers & Bekker 2012), but a large and well-sorted reference collection of seeds from recent plants is invaluable. With the help of a good reference collection, many seeds can be determined to species level.

Sometimes it is not just the species identification that is interesting. In macrofossil analysis, one may also get information about the processing of plants, based on what plant parts are preserved and how they look. Examples are preserved chaff remains (from threshing grain), sprouted kernels of barley (from malting in connection with beer brewing) and burnt lumps of seeds of linseed or gold-of-pleasure (from pressing oil during heating).

Figure 4.3. Floatation to retrieve charred plant macrofossils on an archaeological investigation site. Photo: Per Lagerås.

Data presentation

The results of pollen analysis are often presented in pollen diagrams that show how the percentage of different pollen types varies from layer to layer throughout a sediment sequence. And because the sediment sequence in most cases represents a time development, variations in pollen composition represent vegetation changes through time. What is important to know, however, is that pollen percentage is not the same as relative vegetation cover, even though they are positively related. This deviation is because different plants produce and disperse different amounts of pollen. It is not just that wind-pollinated plants spread much more pollen than insect-pollinated ones – there can also be big differences in pollen production between different wind-pollinated species. To some degree these differences can be compensated for by modelling (see below). Examples of underrepresented taxa are linden (which, unlike most other northern European trees, is insect-pollinated), wheat, and barley (which unlike, for example, rye, are largely self-pollinating). For wheat and barley, the pollen grains are probably dispersed mainly in connection with threshing.

Plant macrofossils are more complicated to present graphically than pollen and are therefore often presented in tables or spreadsheets, and more often in absolute numbers than as percentages. This is because both the number and the species composition of plant macrofossils usually varies greatly between samples. That is particularly the case in archaeological contexts, where species composition to a large degree is due to human action and to the specific function of the sampled feature. For example, a sample from a storage pit may contain thousands of charred cereal grains, while a contemporary sample from an adjacent hearth may contain only charcoal and a few ruderal plants that grew around the fire. Therefore, the presence of various plant macrofossils in different features at a settlement can be used to interpret domestic activities and the organization of the settlement, and above all it provides direct information about human interactions with plants, both cultivated and otherwise.

Chronological control

Dating is fundamental in palaeoecology, especially when results are to be compared with other sources of information, like written documents or archaeological data. In a peat sequence that has been analysed for pollen or macrofossils, the relative chronology is self-evident: the samples become younger upwards in the stratigraphy. But to obtain an absolute chronology, C14 dating is usually required. Suitable plant material for dating can be taken from the peat core itself. Usually, a few levels are selected for C14 dating, and based on the results the levels in between can be dated by interpolation. However, since C14 dating can hardly be used for the last approximately 300 years, absolute dating of later periods is usually problematic. This may partly be solved by using Pb210 dating, which can be used for dating the last 100-150 years.

Macrofossil samples (and for that matter also pollen samples) taken directly from house remains or other archaeological features are not to the same degree dependent on C14 dating. This is because they are already contextually linked to the human activities that are investigated, and which may be dated by other methods. Especially when one wants to study the land use and ecological effects of a specific settlement – for instance a medieval village or a post-medieval croft – it is good if samples are taken directly in the archaeological contexts, and not only, for example, in an adjacent peatland. Such on-site sampling ensures a strong chronological connection between archaeology and palaeoecology.

Modelling past vegetation cover using pollen data

Traditional pollen analysis, where interpretations are based on pollen percentages, has in recent decades been supplemented with modelling. Thanks to thorough basic research, we now have a pretty good idea of how much pollen different plants produce (so called pollen productivity estimates), at least for those plant taxa that dominate most vegetation types (like most trees, grasses, heather, etc.) (Broström et al. 2008). We also have estimates of how easily different pollen types are dispersed by wind (based on measured fall speed of pollen grains). By using this information, together with information about the radius of the sampled lake or wetland, it is possible to model the approximate land cover of different vegetation types based on the pollen counts (Gaillard et al. 2010, Sugita 2007).

Percentage pollen diagrams are still very useful for the interpretation of relative changes in vegetation and land use through time, and for the identifying and dating of, for instance, periods of agricultural expansion and decline. However, when it comes to quantifying the areal extent of vegetation types or land-use, the new modelling techniques have made important contributions and partly changed the picture of past human impact. Because many cultivated plants are weak pollen producers (especially most cereals, but also many other herbs indicative of open landscapes), the extent of agricultural land, such as fields, meadows, and pastures, has often been underestimated in studies based on pollen percentages alone. The new techniques show that past landscapes in many areas had much more open vegetation, and that agricultural land was more widespread than previously thought (Figure 4.4).

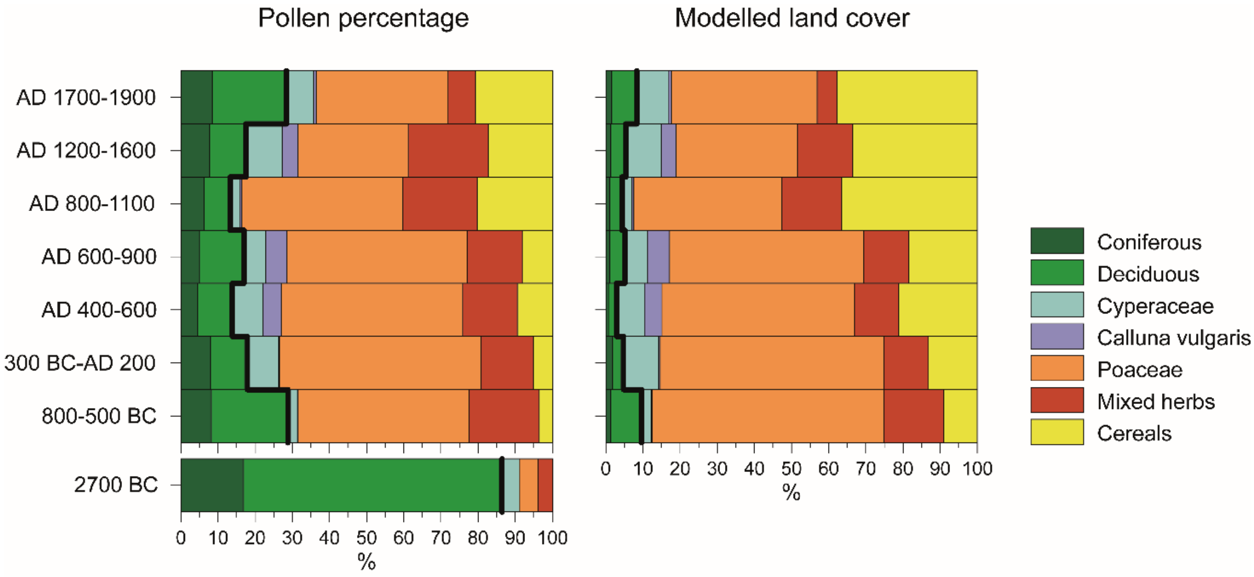


Figure 4.4. Compilation of pollen data from archaeologically investigated wells in southwestern Scania, southern Sweden. Each time window is represented by one or several wells. The left diagram shows pollen percentages whereas the right one shows modelled vegetation cover based on the same pollen data (REVEALS model; Sugita 2007). The modelling shows that the landscape was even more treeless than what is suggested by the pollen percentages. From Lagerås & Fredh 2020.

Temporal and spatial resolution - the importance of careful sampling

Many early pollen diagrams had a rather poor chronological resolution, that is, they had few analysed levels per thousand years. Often this resolution was sufficient in a geological perspective, where it was the long-term trends in vegetation and climate that were of interest. Today, pollen analysis is frequently used to study more short-lasting phases in vegetation and land use – it may be temporary cultivation phases, or periods of abandonment and woodland re-growth due to pandemics. It may also be vegetation response to sudden climatic changes, for instance due to volcanic eruptions. Similarly, Historical Ecology usually focuses on rather short time scales.

For pollen analysis to make meaningful contributions to Historic Ecology, high temporal resolution is necessary. How high depends on the research questions, but as a rule of thumb one should have at least 20 samples per thousand years, preferably more. Twenty samples per thousand years means 50 years on average between the analysed levels. With poorer resolution, short-lasting farms, for instance, may have been both established and abandoned between two pollen analysed levels. The important point, however, is that the chronological resolution shall fit the research questions.

In macrofossil analysis of samples taken in archaeological contexts, it is possible to study very short-lasting events and processes, like the handling of a single harvest, threshing, cooking activities, etc. A limitation when working with samples from archaeological remains, however, is that the palaeoecological record is entirely dependent on human activity. Periods when a settlement is deserted leave no archaeological traces and it becomes difficult in such cases to study re-growth and other ecological effects of the abandonment.

In most palaeoecological projects, it can be very valuable to combine macrofossil analysis of archaeologically investigated settlement remains with pollen analysis from an adjacent peatland. The latter would give an overview of the long-term development of vegetation and land use, whereas the macrofossil analysis would provide less continuous but more detailed information about species composition, plant utilization and human activities.

In terms of spatial resolution, it is important to note that pollen analysis and macrofossil analysis by themselves rarely tell exactly where the vegetation was. Here, the palaeoecological data often needs to be combined with data from archaeological or historical sources. Old historical maps and fossil arable fields are two types of source material that can tie palaeoecological interpretations to past landscapes and land-use patterns on the ground.

A general rule is that it is much easier to integrate paleoecology into interdisciplinary Historical Ecology when working locally. Pollen analysis of a core from a small peatland, adjacent to, for example, a medieval village, provides much better conditions for comparing the different types of data, than does pollen analysis of a core from a large lake. The latter will give an overview of the vegetation development in a large area around the lake, making it difficult to link the results to any specific settlements or to archaeologically investigated remains.

Figure 4.5. Sampling of an Iron Age well for pollen and macrofossil analysis. Photo Per Lagerås.

Disciplinary traditions and publishing

In Sweden, the academic training in pollen analysis, as well as the methodological development, is mainly in Quaternary geology, but in other countries it can be, for example, in historical geography, forest ecology, archaeology, or botany.

Macrofossil analysis, like pollen analysis, used to be an important method in Quaternary geology. It is still used, but now its main use is in archaeology. Most people who work with macrofossil analysis are connected to archaeological university institutions or to private companies, museums, and institutions engaged in rescue archaeology.

Both pollen analysis and macrofossil analysis are time-consuming methods. It may be a problem in university-based research, particularly in the natural sciences, where high speed is rewarded. On the other hand, the development of big-data analysis in recent decades has led to a great demand for palaeoecological data, particularly pollen data.

The results of palaeoecological studies are frequently published in international scientific journals, such as Vegetation History and Archaeobotany, The Holocene, and Environmental Archaeology. Particularly pollen-analytical studies in this way follows the publishing tradition of natural sciences. However, studies carried out in collaboration with archaeologists are sometimes published only in non-English papers, popular journals, books by local Museums, and reports. This is particularly true for macrofossil-analytical studies, of which many are presented only in archaeological reports and other gray literature.

Further reading

An excellent, updated, and very thorough introduction is the second edition of Handbook of plant palaeoecology (Cappers & Neef 2021), which is a useful resource also for the experienced palaeoecologist. There are also useful entries on both macrofossil analysis and pollen analysis in Encyclopedia of Quaternary Science (Birks 2007; Gaillard 2007). Early classics that are still very useful and may be found in your university library are Quaternary palaeoecology (Birks & Birks 1980) and Handbook of Holocene palaeoecology and palaeohydrology (Berglund 1986). Useful introductions may also be found in handbooks on environmental archaeology (Reitz & Shackley 2012). The palaeoecological study of human-plant interactions – particularly if based on plant-macrofossil analysis – is also referred to as archaeobotany, and it is also included in the wider scope of paleoethnobotany. Several good introductions can be found under such headings.

Case study I: macrofossil analysis of a medieval village

This case study gives an example of how plant-macrofossil analysis may be used in archaeological investigations. The site was the medieval village of Fjelie, situated just outside Lund in southernmost Sweden, and the archaeological excavation was carried out in 2016 (Lindberg & Sabo 2019). In connection with the excavation, a whole range of palaeoecological and zoo-archaeological methods were used to shed light on agrarian land use and ecological conditions at the time of the settlement (Lagerås & Magnell 2020). I will focus here on the macrofossil analysis.

Fjelie is situated in an area of very fertile soils, which today it is heavily cultivated. According to a map from 1769, the village at that time consisted of 22 farms, some cottages, and a church (Figure 4.6). The farms were run by tenants and the primary landowners were the church and the nobility. Most of the farms were later moved from the village core in connection with land reforms. Today, a Romanesque church, dated to the early 12th century, is the only visible reminder of the village’s medieval origin.

Figure 4.6. Map of Fjelie village from 1769/1770. Blue line indicates the archaeological investigation site. From Lagerås & Magnell 2020.

The excavation covered three abandoned farmsteads, labeled 18, 19, and 22 on the 1769 map. By the time of excavation, the area was used as arable land, but the farmsteads were readily distinguishable in archaeological structures beneath the modern plough layer. Different generations of buildings could be followed back at least to the 13th century. Preserved archaeological structures were floor and destruction layers, post holes, sills, ovens/fireplaces, and other domestic features. Outside the buildings there were wells and cultivation layers. The find material reflected everyday life.

115 samples (144 litres of soil) from different contexts were analysed for plant macrofossils. Most samples only contained charred remains, but four samples from wells also contained uncharred plant remains. More than ten thousand plant macrofossils (mostly grain and seeds) were identified. They were dominated by cereals, followed by weeds and ruderals, plants of pastures and meadows, and plants of lakes, fens, and wet grassland. In smaller numbers there were also macrofossils representing cultivated vegetables, marine plants, spices and medicinal plants, and collected berries, nuts and fruits.

Cereal grain was strongly dominated by barley, followed by rye, oats, and bread wheat. The plant macrofossils also included several taxa that indicate garden cultivation, such as vegetables and root crops, like pea (*Pisum sativum*), faba bean (*Vicia faba*), and turnip (*Brassica rapa*), and spices and medicinal plants, like black mustard (*Brassica nigra*), motherwort (*Leonurus cardiaca*), dill (*Anethum graveolens*), and caraway (*Carum carvi*). They also included wild marjoram (*Origanum vulgare*), chicory (*Cichorium intybus*), and henbane (*Hyoscyamus niger*), although these species may also have been part of the weed flora. Flax (*Linum usitatissimum*) and hemp (*Cannabis sativa*) probably also reflected garden cultivation, as did a single find of buckwheat (*Fagopyrum esculentum*).

Beer brewing in the village was indicated by sprouted grains of barely, together with fruits of bog-myrtle (*Myrica gale*) and hop (*Humulus lupulus*). The sprouted grains were probably remains from malting, whereas bog-myrtle and hop were common beer additives (Behre 1999; Heimdahl 2014).

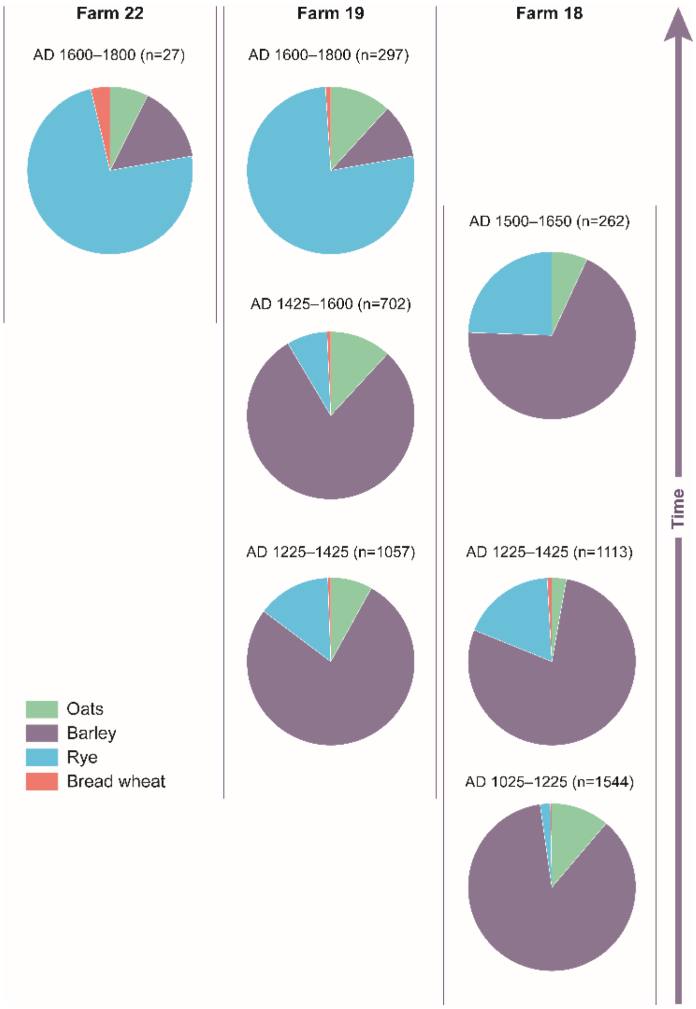


Figure 4.7. Pie charts showing the cereal macrofossil composition of the three investigated farmsteads in Fjelie in relation to chronology. Farm numbers refer to the map in Figure 4.6. From Lagerås & Magnell 2020.

One sample from an indoor fireplace contained charred fragments of seaweed. Two species were identified, bladderwrack (*Fucus vesiculosus*) and sea oak (*Halidrys siliquosa*), which today grow in the Öresund sound, 5 km from Fjelie. The seaweed may have been used for different purposes, like fertiliser, fodder, or fuel, to produce salt or in textile bleaching (Mooney, 2018).

Regarding change in land use through time, in Fjelie the most obvious development was in crop composition (Figure 4.7). Barley was the principal crop in the initial phase of the village. From around AD 1200 both barley and rye were cultivated, and after a further expansion 1600-1800, rye eventually replaced barley as the dominating crop. The onset of rye cultivation in Fjelie coincided with the first appearance of corncockle (*Agrostemma githago*) and rye broom (*Bromus secalinus*, Figure 4.8) in the samples. These weeds thrived particularly in autumn-sown fields, and their presence indicates that rye already from the beginning was a winter crop. Interestingly, the same increase in rye was noted on all the three investigated farmsteads, indicating coordinated infield cultivation by the different farms in the village.

Figure 4.8. Rye broom (*Bromus secalinus*) was a common weed in rye fields in Sweden until the 19th century but is now very rare and categorized as endangered by the Swedish Red List (SLU Artdatabanken 2020). Photo Per Lagerås.

According to written documents, Fjelie and most other villages in the region practised a three-course rotation system, at least from the 17th century onwards. In this system, the infields were divided into three parts, each part used for growing (summer) barley, (winter) rye and for fallow, in three-year's cycles. A plausible interpretation based on the first significant appearance of rye and winter-crop weeds in the macrofossil material from Fjelie, is that a three-course rotation system (or some other kind of similar system) was practised already during the 13th century.

In addition to coordinated and collective practices, like infield cultivation and livestock herding in outland pastures, there seem to have been certain spheres that allowed for diversity and specialization by the individual farms. One of these spheres was vegetable gardening and similar small-scale cultivation. Studies of old maps from southern Sweden have shown that such cultivation was widespread in the countryside at least from the 18th century onwards, and that it was usually practiced on small plots close to the individual farmsteads (Hallgren 2016). For older periods, the picture is less clear, but macrofossil analyses from Fjelie and some other villages prove vegetable gardening already existed during the Middle Ages, at least from the 13th century onwards. This small-scale cultivation may have been an important complement to cereal cropping, and since it was individually managed by the different farmsteads, it was more flexible and enabled diversity and variation according to different preferences, taste, and needs.

The study of Fjelie showed that village agriculture was characterised by diversity in different ways. The combination of several different crops and animals reduced vulnerability to bad weather, crop blights and animal diseases, and the range from highly productive and labour-intensive land use (infield crop growing and garden cultivation) to extensive land use (outland grazing), and probably also the combination of individual and collective, made the system resilient to fluctuations in population.

For a full presentation of this study, see Lagerås and Magnell (2020).

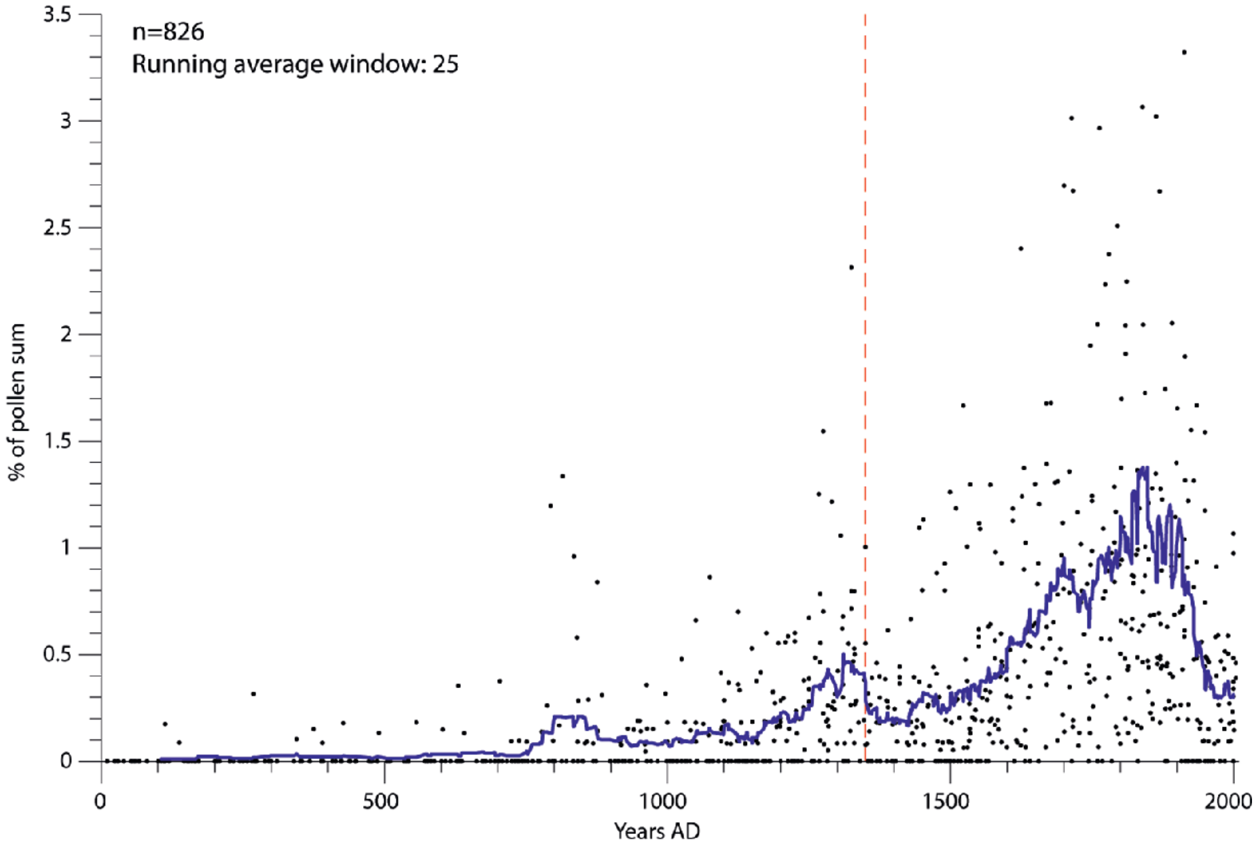


Figure 4.9. Summary of cereal-pollen percentages from 21 pollen diagrams in the South-Swedish Uplands. Each dot represents an original pollen sample with its corresponding cereal-pollen percentage (vertical axis) and original dating (horizontal axis). The samples were sorted chronologically, and a running average was calculated (blue line). Four dots with very high values from the nineteenth century were excluded from the picture but included in the running average. The year 1350 is indicated by a dashed red line. From Lagerås et al. 2016.

Case study II: pollen analysis revealing environmental consequences of the Black Death

In this case study, I present an interdisciplinary research project on the consequences of the Black Death (Lagerås 2016). Several non-written sources were used within the project, like human skeletons from medieval cemeteries, dendrochronological dating of buildings, archaeological documentation, and pollen data. I will focus here on the latter, which were used in the project to study the environmental consequences of the plague and of the crisis that followed (Lagerås et al. 2016). Focus was on quantifying changes in land use and possible farm desertion.

Sweden has a wealth of pollen-analytical studies and many of them, particularly from the last two decades, are detailed and with good chronologies. In some pollen diagrams, declines in cereal-pollen percentages had been noticed at levels corresponding to the late Middle Ages. Such declines may indicate farm abandonment and could hypothetically be connected to the Black Death. To examine this more closely, the research project compiled and analysed many previously published pollen diagrams from southern Sweden. Especially from the South-Swedish Uplands, there were several good diagrams and 21 could be used for a quantitative analysis of land-use change in the uplands.

One of the most striking results was that a summary of cereal pollen from all the 21 upland sites showed a clear decline by the year 1350 (Figure 4.9). It suggested a halving of the total cultivated area in the uplands around 1350, probably as a direct result of population decline and farm abandonment in the wake of the plague. Thus, the pollen record – both pollen percentages and pollen-based land-cover reconstructions – gives support to earlier interpretations of historical records that suggest extensive farm abandonment in upland areas during the late-medieval crisis (Myrdal 2012). Even though a halving of cereal production, as indicated by the pollen record, does not necessarily reflect a farm-desertion frequency of 50% (farms may have survived but reduced their acreage), it indicates that a desertion frequency of that size is not at all unlikely.

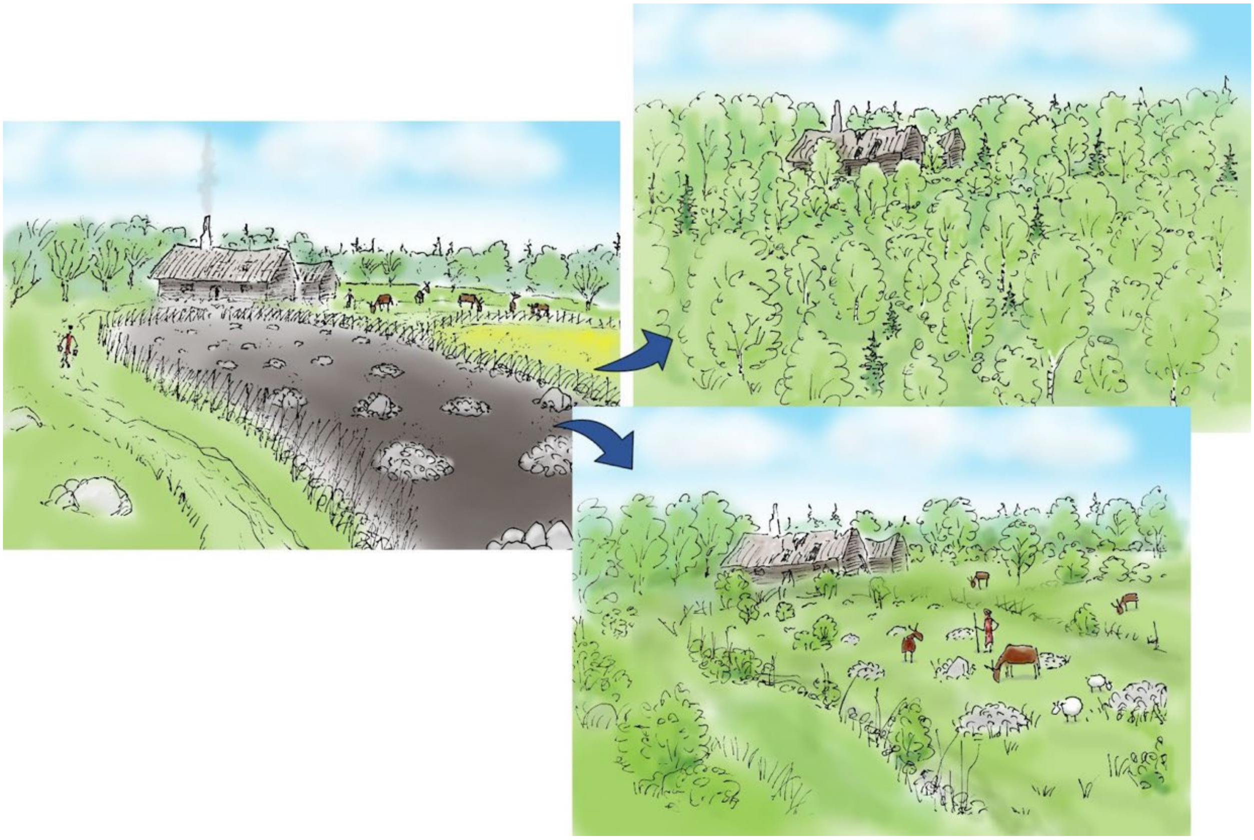


Figure 4.10. Two alternative types of farm abandonment in the wake of the Black Death in the South-Swedish Uplands identified by pollen analyses: woodland regrowth (upper right), or extensive grazing by neighbouring farms (lower right). Drawings Per Lagerås.

Another interesting result concerned the extent of grasslands and the degree of overgrowth. Pollen data (and dendrochronological data) showed that some abandoned agricultural land was overgrown by woodland in the wake of the plague. Pollen data thus confirm the generally held belief that forest cover increased during the crisis, at least in marginal uplands. The abandonment of fields, in combination with decreased grazing pressure in pastures, enabled the sprouting of shrubs and trees and started a process of natural woodland succession. Pollen data showed that particularly birch woodland expanded, but there was also regeneration of oak and pine and to some degree spruce. Several forest plants and animals must have been favoured by this change, particularly those associated with light, early-successional woodland.

But not all abandoned farms were overgrown by forest. Especially in the lower parts of the uplands, the landscape was kept open, even though the amount of arable land decreased. The proportion of grassland taxa continued to be high, while there was no or very little increase in tree pollen. A plausible interpretation is that the lands of abandoned farms were used for grazing and occasionally for hay mowing, which kept the landscape open by holding back the forest. Hence, in addition to reforestation, another vegetation change was associated with the Black Death, that is the turning of arable fields into pastures and meadows. When cultivation ceased, the immediate effect would have been enhanced flowering of annual weeds, but soon a grass sward would develop and a rich flora of perennial herbs typical of grazed and mowed environments would take over.

To conclude, abandonment was widespread all over the uplands, but reforestation was restricted mostly to the higher parts of the uplands (which had the poorest natural conditions for agriculture), whereas the lower parts to a large degree were kept open by grazing and possibly mowing (Figure 4.10).

The most apparent vegetation changes after the Black Death, such as the expansion of birch woodlands, lasted for about two hundred years, until the sixteenth century. Pollen data showed that by the late sixteenth century, the re-establishment of arable fields, meadows and pastures had again replaced much of the secondary woodland. There may, however, also have been more long-lasting ecological effects. Dendrochronological data showed that some trees, particularly of pine, that germinated in connection to abandonment in the mid-fourteenth century, lasted for several hundred years. They were the oldest tree generation of the forest for a long time to come. Still in the early eighteenth century there were living trees that had once germinated in connection to the Black Death. By that time, they were about 350 years old. Such old trees are usually the home for many plants and animals, like fungi, lichens, and insects, and contribute significantly to the species richness of forests. We may therefore conclude that the Black Death of the mid-fourteenth century still affected biodiversity more than three hundred years later.

For a full presentation of this study, see Lagerås et al. (2016).

References

Behre, K.-E. (1999). The history of beer additives in Europe - A review. Vegetation History and Archaeobotany, 8, 35–48. https://doi.org/10.1007/BF02042841

Berglund, B. E. (Ed.) (1986). Handbook of Holocene palaeoecology and palaeohydrology,. Wiley.

Beug, H.-J. (2004). Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete. Dr Friedrich Pfeil.

Birks, H. H. (2007). Plant Macrofossil Introduction. In Encyclopedia of Quaternary Science (pp. 2266–2288). Elsevier. https://doi.org/10.1016/B978-0-444-53643-3.00203-X

Birks, H. J. B., & Birks, H. H. (1980). Quaternary palaeoecology. Edward Arnold.

Broström, A., Nielsen, A. B., Gaillard, M.-J., Hjelle, K., Mazier, F., Binney, H., Bunting, J., Fyfe, R., Meltsov, V., Poska, A., Räsänen, S., Soepboer, W., Von Stedingk, H., Suutari, H., & Sugita, S. (2008). Pollen productivity estimates of key European plant taxa for quantitative reconstruction of past vegetation: A review. Vegetation History and Archaeobotany, 17(5), 461–478. https://doi.org/10.1007/s00334-008-0148-8

Cappers, R. T. J., & Neef, R. (2021). Handbook of plant palaeoecology. (2nd revised ed.). Barkhuis.

Cappers, R. T. J., Bekker, R. M., & Jans, J. E. A. (2006). Digitale Zadenatlas van Nederland. Barkhuis.

Gaillard, M.-J. (2007). Pollen methods and studies: archaeological applications. In Encyclopedia of Quaternary Science (pp. 2570–2595). Elsevier.

Gaillard, M.-J., Sugita, S., Mazier, F., Trondman, A. K., Broström, A., Hickler, T., Kaplan, J. O., Kjellström, E., Kokfelt, U., Kuneš, P., Lemmen, C., Miller, P., Olofsson, J., Poska, A., Rundgren, M., Smith, B., Strandberg, G., Fyfe, R., Nielsen, A. B., … Seppä, H. (2010). Holocene land-cover reconstructions for studies on land cover-climate feedbacks. Climate of the Past, 6(4), 483–499. https://doi.org/10.5194/cp-6-483-2010

Hallgren, K. (2016). En kåhltäppa eij at räkna. Köksväxtodlingen i 1700-talets jordbrukssystem. Sveriges Lantbruksuniversitet, Fakulteten för Naturresurser och Jordbruksvetenskap.

Heimdahl, J. (2014). Brewing an Ethnic Identity: Local and Foreign Beer Brewing Traditions in 15th- to 17th-Century Sweden – an Example from Nya Lödöse. In M. Naum & F. Ekegren (Eds.), Facing otherness in Early Modern Sweden (pp. 61–85). Boydell and Brewer.

Lagerås, P. (Ed.). (2016). Environment, society and the Black Death – an interdisciplinary approach to the late-medieval crisis in Sweden. Oxbow Books.

Lagerås, P., Broström, A., Fredh, D., Linderson, H., Berg, A., Björkman, L., Hultberg, T., Karlsson, S., Lindbladh, M., Mazier, F., Segerström, U., & Sköld, E. (2016). Abandonment, agricultural change and ecology. In P. Lagerås (Ed.), Environment, society and the Black Death – an interdisciplinary approach to the late-medieval crisis in Sweden (pp. 30–68). Oxbow Books.

Lagerås, P. & Fredh, E. D. (2020). Long-term development of landscape openness and arable land use in an agricultural region of southern Sweden: the potential of REVEALS estimates using pollen records from wells. Vegetation History and Archaeobotany 29, 113–124. https://doi.org/10.1007/s00334-019-00756-z

Lagerås, P., & Magnell, O. (2020). Resilient Land Use in the Medieval and Early-modern Village: Crop and animal husbandry in Fjelie, southern Sweden, AD 1000-1800. Danish Journal of Archaeology, 9, 1–24. https://doi.org/https://doi.org/10.7146/dja.v9i0.118779

Lindberg, S., & Sabo, K. S. (Eds.). (2019). Bytomt och boplats i Fjelie: inför ombyggnad av väg E6.02. Arkeologisk undersökning 2016. Arkeologerna, Statens historiska museum, Rapport 2019:10.

Mooney, D. E. (2018). Charred Fucus-Type Seaweed in the North Atlantic: A Survey of Finds and Potential Uses. Environmental Archaeology. https://doi.org/10.1080/14614103.2018.1558805

Moore, P. D., Webb, J. A., & Collinson, M. E. (1991). Pollen analysis (2nd ed.). Blackwell.

Myrdal, J. (2012). Scandinavia. In H. Kitsikopoulos (Ed.), Agrarian change and crisis in Europe, 1200–1500 (pp. 204–249). Routledge.

Neef, R., Cappers, R. T. J., & Bekker, R. M. (2012). Digital atlas of economic plants in archaeology. Barkhuis.

Reitz, E., & Shackley, M. (2012). Environmental archaeology. Springer.

SLU Artdatabanken. (2020). The Swedish Red List 2020. SLU.

Sugita, S. (1994). Pollen representation of vegetation in Quaternary sediments: theory and method in patchy vegetation. Journal of Ecology, 82, 88–897.

Sugita, S. (2007). Theory of quantitative reconstruction of vegetation I: Pollen from large sites REVEALS regional vegetation composition. Holocene, 17(2), 229–241. https://doi.org/10.1177/0959683607075837

CHAPTER 5

PLACENAMES AND TOPONYMY

COSMIN IVAȘCU, NILS STANIK

This chapter focuses on the importance of placenames (toponymy) for the research of land use and historical relationship between human communities and their environment over time. Landscapes bear the marks of past land use not only in their physical structure (e.g. terraces, field structure, forest structure, tree shape), but also in the place names that were given by the communities of people living there. Place names are the living memory of the historical landscape. Their meanings may refer to specific land-use systems or practices, important social phenomenon, religious or supranatural beliefs, geographic and geological formations, and also to vegetation and other resources and their use. In this chapter, we discuss the importance of place names regarding past land use and vegetation structure. These categories of place names can complement and complete the research methods presented in this volume (field observation, cartography, historical documents, etc.). More specifically, we focus on place names related to man-made landscape features (fences, walls), pastoralism, specific agricultural practices, deforestation and vegetation types. Comparisons are made between Romanian, Swedish, German and English place names to highlight similarities and differences in landscape structure and land use. In many cases, the realities behind many place names (activities, vegetation etc.) are today absent from the landscape. But their presence in the memory and culture of local communities is a reference to the complex and dynamic relationship between humans and their environment.

Introduction - Between- Geography, Linguistics, Cartography and History

Toponymy is the scientific study of place names from a historical, etymological (linguistic) and geographical perspective. Depending on the academic tradition of each country, toponymy has been considered a subfield either of linguistics or geography. See the following examples from:
The U.K. (https://www.english-heritage.org.uk/visit/inspire-me/origins-of-english-place-names/),
France (https://www.familysearch.org/en/wiki/France_Gazetteers),
Sweden (https://www.familysearch.org/en/wiki/Sweden_Gazetteers),
Germany (https://www.familysearch.org/en/wiki/Identifying_Place_Names_in_German_documents

For an in-depth example, in Romania, the systematic study of place names was first started by human geographers at the end of the XIX century, who started gathering local vernacular words referring to different geographical units (Iordan 1963). In a later development of this scientific discipline, linguists started to focus their attention on toponymy, especially from an etymological viewpoint. This was done in order to identify pre-Roman, Roman, Proto-Romanian, Slavic and toponyms originating from other language groups (Hungarian, Turcique languages etc.) to uncover past connections between the different ethnic groups that were living on the territory of present-day Romania or the continuity of the Romanian people in the Carpathian area (Buza

2011, Homorodean 1980, Iordan 1963, Ioniţă 1982). Thus, historians and archaeologists have also been interested in this domain, as toponymy may reveal events, e.g. of migration and trade, that are absent in other historical sources (Iordan 1963). Toponymy, like biological cultural heritage (see Chapter 3), may be particularly important in landscapes and for land use that are less commonly present in archival sources, for example outside of commonly used settings and arable areas (e.g. Lindholm et al. 2013).

As noted earlier, when it comes to the origin of toponymy as a scientific discipline, in the case of Romania, the first endeavors regarding the study of place names at the beginning of the XIX century was seen as auxiliary science (or rather a field/subdiscipline) of disciplines such as linguistics, geography and history (Cojocaru 2014). Within the Romanian Geographical School, toponymy started to be established as a serious study area especially within Human Geography (or Anthropogeography as it was called before WWII) and its subdisciplines such as Historical Geography (focusing on the study of relationships between local communities and their landscapes by using toponymy, local words and perception (ethnoscience), cartography, and historical documents). A major representative of this research topic in Romanian geography, was Ion Conea who started this undertaking in an extensive monograph of Clopotiva (Conea 2010), a village in Southern Transylvania but also an area from Moldova known as Țara Vrancei (Vrancea Land) being famous for its ethnographic and autarchic structure (Conea 1993). However, most human geographers (Bizerea 1970, Conea 1993, Conea 2010, Idu 1997) and even ethnographers (Vuia 1975) from Romania conducted well documented studies on toponyms and their meaning, but also on complex vernacular ethnogeographical notions found in local speech (Conea 1993, 2010). Linguists as well as historians also had special interest in this field, focusing on the origin, transformations and cross-cultural comparison of toponyms (Cojocaru 2014, Iordan 1963), with some extremely valuable regional monographies on this topic being done by linguists (Ionita 1982, Homorodean 1980).

It is also highly important to note regarding the history of this discipline in Romania, toponymy started to show special interest also to scientists from zoological-ecological research fields. For example, a Romanian biologist Alexandru Filipașcu, using the current extension of toponyms related to now extinct animals (some of them currently reintroduced) like aurochs, bison, beaver, etc. was able to reconstruct their past occurrence and biogeography within the territory of Romania (Filipașcu 1969).

Currently, toponymy has been of great interest also in other research areas such as ethnoecology and more specifically in landscape ethnoecological endeavors (Johnson & Davidson – Hunt 2011). Due to the nature and importance of the outcomes related not only to the physical landscape, but also to biota and land use, toponymy has been successfully integrated in ethnoscience-based research (Hunn 1994, Hunn 1996, Johnson & Davidson, Hunt 2011). In addition to interpreting place names, some ethnoecological investigations of landscapes have highlighted causal relationships between place name density and cultural importance, including the importance for past and current land use (Hunn 1994; Lindholm et al. 2013).

In this chapter, we focus on the use of place names as a source of information about human-nature relationships in the past and present. Such information is embedded in names describing natural resources, ecological conditions, and landscapes and their features, as well as in names describing land use or other human activities. The use of placenames as a historical source relies on the fact that names, just like other types of cultural heritage, may remain long after their meaning is no longer present in culture or the environment. Similar undertakings for reconstructing past land use by including information embedded within certain place names along with other interdisciplinary approaches (vegetation and geography) have been successfully applied also in other European countries, including Switzerland (Conedera et al. 2007).

The actual methods for working with toponymy are described in other textbooks, such as the Oxford handbook of names and naming, part II (Hough 2016). Some researchers consider that there are two main research models in toponymy: a) the etymology (thus on the origin and meaning of the place name), and b) the regional study of encountered toponyms and the distribution patterns (Tent 2015). Although both methods can work and offer important information in historical ecology endeavors (e.g. on activities or vegetation type or structure etc., and the regional dispersal of these). It must be noted that most Romanian human geographers and toponymysts applied both methods in their studies (Buza 2011, Conea 2010, Homorodean 1980, Ioniţă 1982). Here, we focus on the interpretation of place names by combining historical, ethnological and ecological knowledge.

Material and Methods - How and from where to collect data

Toponymy can be studied from several viewpoints, as mentioned above, however, with regard to Historical Ecology, toponymy can be an important source of information since it can complement several of the methods presented in this volume and can show land-use history and landscape dynamics. The first phase of this endeavor is to collect the place names in the study area. This can be done by searching place names on maps from different time periods. By doing this, it will be obvious that names may have changed over time, as well as the current importance of places. For this reason, it might be feasible to consider names at different scales, for example as macro- and micro-toponymes (Man 1996). Macro-toponyms are widely known and used, regionally, nationally or even wider. Micro-toponyms are used more locally, sometimes only among a small group of people such as a family or local community. Small-scale topographic or military maps are good sources of information for macro-toponyms, whereas more detailed information about micro-toponyms can be found in cadastral maps. Many cadastral maps are accompanied by tables and descriptions, which may provide a rich source of micro-toponyms, sometimes one name for almost every place of local land-use importance. However, more detailed information on micro-toponymy in certain areas can be obtained from local experts by interviewing them. Both sources of information (military/cadastral maps and oral information) can complement each other in a very good way.

The main sources of information are historical maps (military or cadastral), local or regional monographs, geographic studies, interviews, and anthropological inquiries.

Several nations today create and provide to the public gazetteers, which are geographical dictionaries including lists of place names, which are often used with Atlases and maps. There are also digital collections of place names, including the Getty Thesaurus of Geographic Names Online
(https://www.getty.edu/research/tools/vocabularies/tgn).

Another aspect of the scale of place names is the level of detail entailed in the names. Some categories of names are widespread since they describe widespread phenomena of the history of human presence in the environment. Examples of activities, frequently found in place names, are settlement, clearing of forest and the general agricultural practices: cultivation, haymaking and pastures. Many names of this type describe general types of ecosystems, such as names depicting various types of forest, wetland, or mountainous ecosystems. Other names are confined to certain, often local, conditions, resources and specialized adaptations of resource-use. They usually provide more detailed and new information than the wide-spread names. The names may, for example, describe details of the general agricultural practices, such as leaf harvest for winter fodder, transhumance grazing or rotational cultivation. Details are mostly found in micro-toponyms, but both micro- and macro-toponyms may be of the less detailed type.

Place names describing a more specialized use of resources may reflect cultural identities and expressions or specific environmental conditions or both. One example of a specific environment being interlinked with a specific culture is the use of arctic-alpine ecosystems by Sàmi reindeer pastoralists. Another example is that a

Finnish population of specialized swidden farmers colonized some forest areas of Sweden during the 17th century and left a wealth of place names relating to swidden cultivation in the forest landscape and also indicating the Finnish origin of the settlers.

The actual meaning of place names may be difficult to understand due to the change of both the names and the language over time. Fortunately, the tracing of names' origin is a well-developed part of toponym research in most languages. Once the meaning of a toponym is known, it needs to be interpreted in order to be used in Historical Ecology. What does the name say about human-environment relationships? All such interpretation requires additional information, such as information about local land-use practices, vegetation and species, and cultural customs. This is especially the case for micro-toponyms. Frequently, names reflect customs that are forgotten and unknown, and we can only guess what the names had to say to earlier generations.

Even if maps can be considered as an important tool in the study of toponyms, in some cases one can observe some discrepancies among place names found on historical maps and actual living place names. As an example, on the Hapsburg Cadastral map of the village Ieud (1863) in Maramureş (Romania) some places names are written as Gruniul (Gruniul Lupului, Gruniul Porcului), while during recent fieldwork we noticed the locals used the place names Grâul Lupului and Grâul Porcului. Between those two words there is a considerable difference, because grâu means wheat and gruni or grui is an ethnogeographic notion for a plateau on a hill, also widespread in the Romanian Carpathians. Both place names can suggest certain land-use practices, like wheat cultivation on the one hand or a relief unit on the other hand that was also subject to certain agro-pastoral practices.

There are normally no modern maps that present micro-toponyms as detailed as cadastral maps. If we want highly local names for the present or near present it is usually necessary to conduct semi-structured interviews or questionnaires to knowledgeable members of the local community (local experts) together with a map. Although the map is not mandatory, it is better when the interview is done with the help of it. Another method that can be employed would be doing a trip with locals within the landscape to gather this kind of information (of course if there are any members from the community that are willing to do this or have the necessary time for this kind of activity). However, the most convenient method is by gathering oral information together with a map, which is the same as doing a semi-structured interview and has the advantage that beside the place name the researcher can obtain additional information regarding the meaning of the toponym, for example how it links to current and previous land use. This method is very useful for the collection of micro-toponyms that are often not charted even on detailed maps, besides obtaining very important additional information on each placename. The researcher must bear in mind that some local explanations of a place name's meaning are not always valid, since the name may refer to past agricultural practices that are now forgotten. (the case of runc or secătura will be discussed below). For example, the place name Arşiţa and even Secătura is explained by many locals as deriving from the topography, as being a terrain that is permanently sunny and dry. This is an explanation which is not correct, due to the fact that both the aforementioned toponyms refer to specific deforestation techniques used for obtaining grasslands or fields, as presented below. During the process of interviewing a local expert, the researchers will notice that different people within a community will have more information on a certain part of the landscape, due to several reasons like owning land in that area or living near a specific place etc. This is one of the reasons why it is important to previously identify the local experts within a community and try to do interviews with as many members of the community as possible.

On the other hand, sometimes even though most local etymologies can be incorrect from a scientific point of view (regarding the etymology or origin of the word), like in the aforementioned example, there are cases where the local explanation can be correct, or the additional information can help us understand the practice behind a certain micro toponym. For example, in the village Forotic from Caras-Severin county, Romania, we found the micro-toponym Târsoane for a forested hill within a large area covered with old growth forests. In the local speech of the Caraș Valley ethnographic area, a târsâ means to clear an area from unwanted woody vegetation. Thus, the place name Târsoane would indirectly show that in the past, clear cuts or deforestation practices were done on that hill nowadays covered by old growth forest (mostly *Quercus petraea* and some *Fagus sylvatica*). However, the name alone could not give any information on the technique used or land use history. Investigating further for explanations of this micro-toponym or the existence of oral histories related to that area, some people remembered stories that in the past in the respective area locals would produce charcoal. Thus, the additional information was of crucial importance for understanding the origin of the place name and the land use history behind it.

Other sources of information on the toponyms existing in a certain area or village, could be village monographs or regional monographs. Village monographs usually contain demographic, historical, cultural and ethnographic information, but also include some chapters or subchapters on the toponymy of the village and surrounding areas. Depending on the authors and their interest, some might include extremely detailed information, or some could be less detailed or even ignore this subject.

General importance of toponymy for Historical Ecology

Historical Ecology is largely about the mutual relationships between ecosystems and human activities in the landscape in an historical perspective. One key to understanding such relationships is to get information about past activities and past ecosystems and environmental conditions. Here, place names may contribute with three types of information, in particular:

The first is information about earlier land use that is no longer present and also not depicted in historical maps. Landscapes far from settlements are often especially poorly described in maps and other archival sources. Large areas may be depicted as forest, although we know or suspect that they have been subject to a variety of activities for resource-use: charcoal burning, swidden cultivation, cattle grazing, fishing, hunting, and various types of reindeer herding. Here, micro-toponyms, ethnology and biological cultural heritage are our main sources of knowledge about these former land uses.

The second type is information about details of past land use and ecosystems. The general types of land-use - haymaking, cultivation, grazing and so on - may be seen in maps, but place names may reveal details about when and how the mowing was done, what kind of vegetation was managed etc. So we need to consider there might be certain place names that can help us understand about the temporality of a practice but also the historicality of it (how long it was in use and the extent of the seasonal use).

A third type of important Historical Ecological information that can be obtained from place names is that a change of names over time may indicate changes in land use, landscape, and culture. These types of toponyms can help us follow land-use continuity and discontinuity or a shift in subsistence strategies, within certain human communities and within certain regions, which show also the adaptive nature of human land use.

Placenames as a reflection and reference of historical land use. Their importance for understanding landscape and social dynamics through the centuries.

A famous Romanian linguist considered toponymy to be: "...the unwritten history of a people, an actual archive, that bears the memory of so many events and data… " (Iordan 1963, p. 2). In the following section we will highlight the importance of place names for understanding local land use and landscape history in some specific case studies. We will demonstrate that there is no accidental distribution of place names within a given landscape and in many cases some toponyms signify specific agricultural practices, many of which are no longer practiced in the community. Other examples of toponyms will provide us with valuable information on the vegetation structure or even on the history and dynamics of some ecosystems. We will also discuss the man-made landscape features and their continuity in the collective memory.

In the following sections, we exemplify both wide-spread and local place names related to diverse aspects of human use of the landscape.

Placenames indicating deforestation or certain deforestation practices

Among the more widespread place names we find names related to clearing of forest for settlement, which has accompanied human expansion everywhere except for naturally non-wooded biomes. Before human settlement and land use, most areas of Europe were covered with forest, deciduous forests in the south and in lowlands, and coniferous forests in higher latitudes and altitudes. Settlement, cultivation, and haymaking always required clearing of the forest, and place names related to deforestation are very common among many regions of Europe. In the Romanian Carpathians, there are over 30 different toponyms that signify a practice linked to deforestation. It is common that the name of the practice of deforestation is transferred to the area. Such as when an area that has been cleared becomes a clearing. In many languages, place names frequently end or begin with a word denoting a cleared area, thus referring to the area originally cleared, e.g. for settlement. Examples are German -rode or related suffixes (Berger 1999), Swedish -ryd, -röd and similar, all meaning clearing. Many English place names end with -ley, from the old English leah, for wood-clearing (Hough 2016). Another common type of toponyms indicating deforestation are words for felling (of trees), such as in Swedish -fall-, fäll- and similar. Another Romanian word for a deforestation practice is curătura and has the exact meaning as the English word clearing.

In some cases, these toponyms indicate not only the practice of deforestation, but also the method used by the local communities. For example, the place name Secătura is found on many historical maps but also in many mountainous landscapes within Romania. It is present in Maramureş and also in the village of Ieud from this region (Figure 5.1). When interviewed, locals from Ieud did not know the origin of the place name, which is also found on many Habsburg Military Maps depicting this village. However, other researchers recorded that secătura denotes an area which has been cleared through first ring-barking and then felling the trees (from Romanian seca or a săcui, meaning to dry out). The etymology of this word originates from latin siccare or the latin verb secare, meaning both to dry out and to cut down, to fell (Matei et al. 1998).

This method of removing trees from certain areas of a village territory was documented as late as in the 1980s in some scattered and isolated villages in the Southern Carpathians (Apolzan 1987). In the Luncani Plateau within the Southern Carpathians, the notion and the technique of a seca is still known even nowadays by the locals, being a living concept. Within this man-made plateau, in the village Târsa (another regional word depicting deforestation in Southern Transylvania and Banat), the locals currently used the word a seca to describe the clearance of bushes and other unwanted woody vegetation through ring barking but especially on meadows. Other variants of this toponym are saca, secu, săciu.

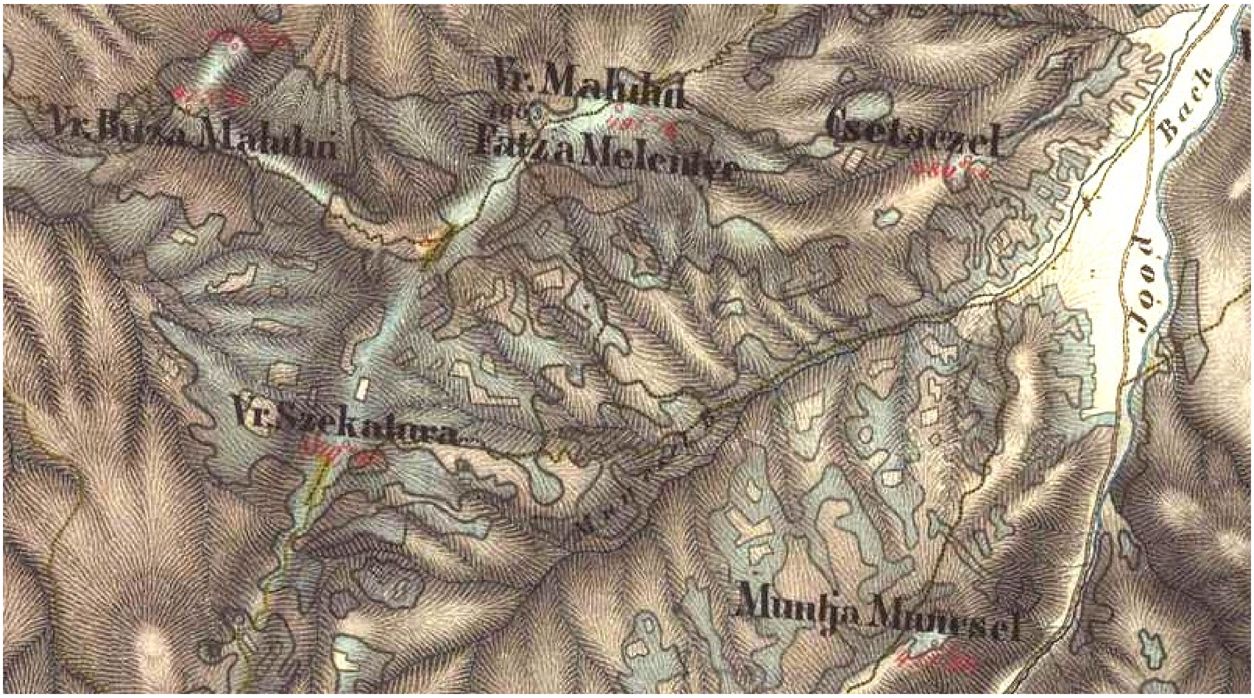


Figure 5.1. The toponym **Secătura** on the territory of the Village Leud from **Maramureş** depicted on the Second Military Survey (Franziszeische Landesaufnahme).

In other areas of Romania other terms can be used by locals for the practice of ring barking, for example in some mountainous areas of Banat this action is called certejit, giving birth also to toponyms like Certeju, Poiana Certeji and other variants (Ioniţă 1982, Ioniţă 1976). In Maramureş the term ciung and the verb a ciungi are commonly used for this practice, although in the past and in some other areas this word would signify a different practice. For examples toponyms like Ciungii **Bălăsânii** (found in Maramureş) or Ciungi found in other areas of the Romanian Carpathians derives from the word ciung, which means crippled but when it refers to trees it means lopped, branchless, a dying wood. Thus the toponyms containing the word ciung would refer to places where the trees removed via lopping them down and not by ring barking solely. In Poiana **Ruscă** Mountains the practice of a ciungi referring to lopping down a tree (especially birch trees for preventing resprout on grasslands) or cutting it down from around half a meter distance from the ground is still used by some locals and it is not confused with ring barking of a tree. The term ciung and ciungar have the same meaning also in Banat, lopped trees, the toponym containing this word being quite common in mountain areas from this region, e.g. Poiana cu Ciungi (Glade of lopped trees), Pogara cu Ciungi (Burnt patch with lopped trees) etc (**Ioniţă** 1982).

In deciduous forest, ring-barking may have been the most important way of removing certain tree species. Without it, cut trees rapidly produce new shoots from the stump or roots, making clearing a labor-intensive process. In contrast to deciduous forest, coniferous forest is more prone to fires, and in such forest types, burning may have been more common, which is reflected in toponyms all over Europe, but especially in areas with coniferous forest, which is easier to burn than deciduous forest. Romanian toponyms like **arşiţa** (derived from the word ars meaning burnt) and jariştea (from the word jar meaning embers, jariştea would be a place of former embers) is an example of mainly semi-natural grasslands (sometimes even cultivated terrains) obtained by setting fires to forest or coppiced/lopped trees.

In Sweden, there are several terms for burning of forest and the diversity of terms reflects dialectal differences, age of the terms, and differences in burning practice (Figure 5.2). These place names are found both on cadastral and military maps and also in the collective memory of the communities. Their distribution is also found in hilly and mountainous areas and in many cases with connection to grasslands or other agricultural terrains. Their place names highlight also the method by which these grasslands were obtained, which is setting fire to the forests and then using the burned areas as grasslands.

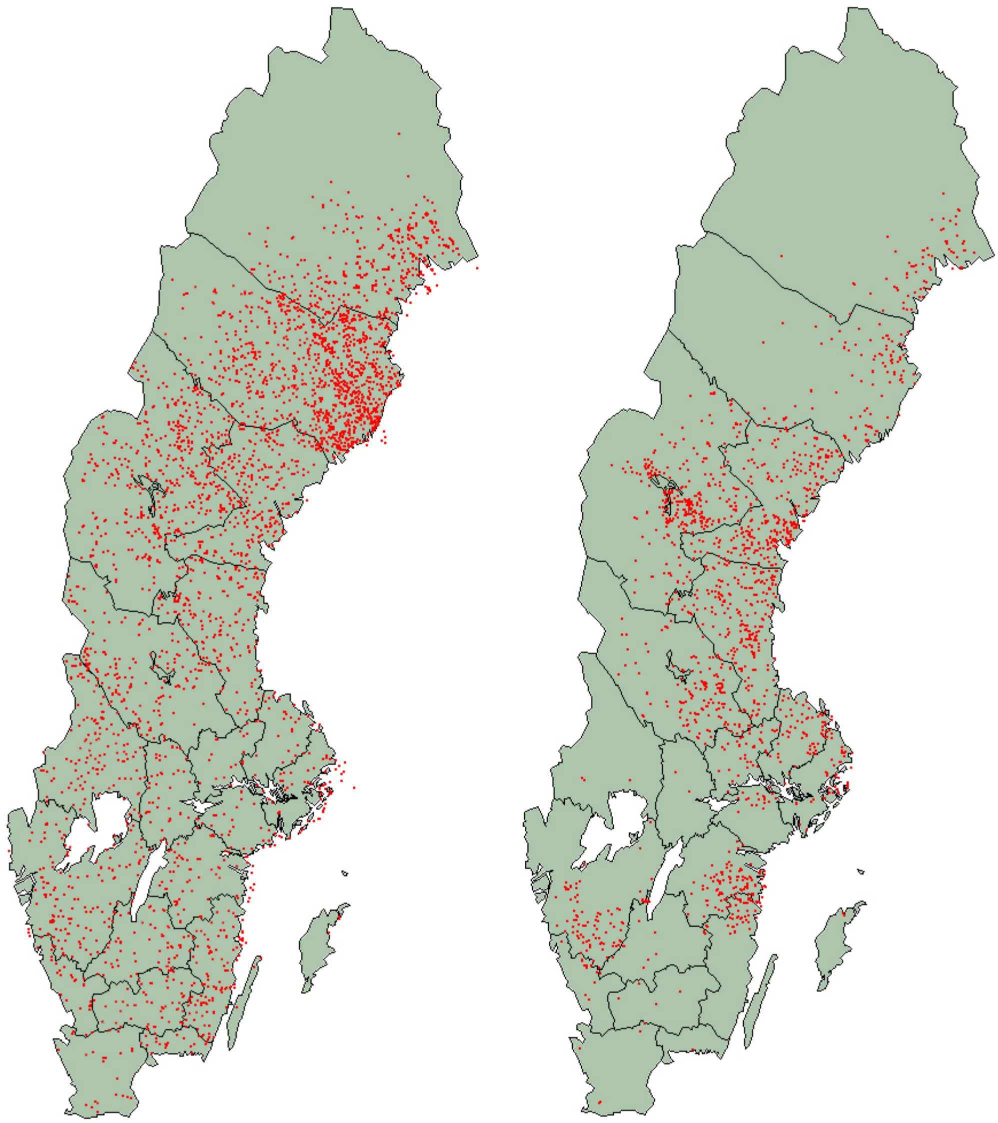


Figure 5.2. Toponyms in Sweden containing varieties of the word burn, Sw. -sved-, -svid- (left) with varieties of swidden, Sw. -finn- (right). Differences partly describe different practices, partly dialectal differences. Source: svenskt ortnamnsregister. Illustration: Tommy Lennartsson.

The burning of forest has often been combined with swidden agriculture ("slash and burn"). After burning, it was common to take one or two cereal harvests before the burnt area was let to grazing or mowing. This practice is partly illustrated by the different distribution of words for burning forest (Figure 5.2).
Runc is a place name found all over the Carpathians that indicates a pasture or a hay meadow obtained via deforestation (Figure 5.3). Some researchers suggest that this practice (runcuirea) would be done with the help of the ax and would imply cutting the trees from a certain terrain (Idu 1997). Runc, in some areas like Bucovina (Romania) is a place name designating a grassland obtained by clearcuts and afterwards maintained by grazing with livestock. In some cases, the runc was also cultivated with crops for some periods and afterwards being transformed into a meadow. A similar toponym/word (ronco/ronchi) is found also in the Apennines indicating a complex swidden agricultural system (the cultivation of cereals in woodland implying cyclical hoeing, controlled fires and coppicing) (Cevasco 2004). The toponym runc derives from the Latin runcus and ancient Greek rhynkos, meaning forest clearing and is also currently the most widespread toponym on the territory of Romania (around 150 recordings) (Idu 1997). Although in most areas of Romania, runc remained simply a toponym, according to the second volume of the Romanian Ethnographic Atlas done during 1972 and 1982 (Ghinoiu 2005), there were still around three villages in Southern Transylvania (in the area of transhumant shepherds) and three other in Southern Romania (Wallachia) that used the word runcuire for designating a deforestation.

In Italian the word runc has maintained its meaning to hoe or to stub (to dig up) (Conedera et al, 2007, p. 738). The runcus base has given rise to similar toponyms also in other regions of Europe, for example Ragore in Switzerland (Kuhn 2002). Another example of a toponym derived from Latin is the French Sauveplane and Salveplane, from silvam planam, cleared wood (Astor 2002).

Figure 5.3 shows the partial distribution of toponyms related to different techniques of deforestation on the territory of Romania created by Petru Dan Idu (1997, p. 236). It can be noted that runc is one of the most widespread toponyms, being found also in the hilly areas and lowlands in Moldova and Wallachia, areas which were also covered by decidual forests until mid XIX century.

It is worth with noting that in the village Jina (Southern Transylvania), well known for the former transhumant shepherds originating from here, there are three toponyms related to deforestation (runc, saca and arşiţa) found on terrains used nowaday as hay meadows (Matei et al, 1998). This also shows that these grasslands were obtained by different practices (clear cut, ring barking and setting fire) of deforestation.

Laz is another toponym very frequently found all over the Romanian Carpathians, connected to a forest clearing (from slavic laz). In Ieud two toponyms are connected to this practice: Sub Lazuri and Lăscior. However, here the verb a lăzui is still used by the locals and it means cleaning meadows from bushes and shouts, not directly linked to deforestation, but to the management of grasslands. In a collection of folklore from Maramureş, dating back to 1908, the word laz is explained as: a place for making hay (Bud 1908, pg. 79). Laz is also widespread in other areas of Romania for example it is quite common in the region Banat: Obârşia (descent of) Lazului, Valea (valley of) Lazului, Culmea (summit of) Lazului and so on. Around 49 toponyms containing the word laz have been found so far on the territory of Romania (Idu 1997).

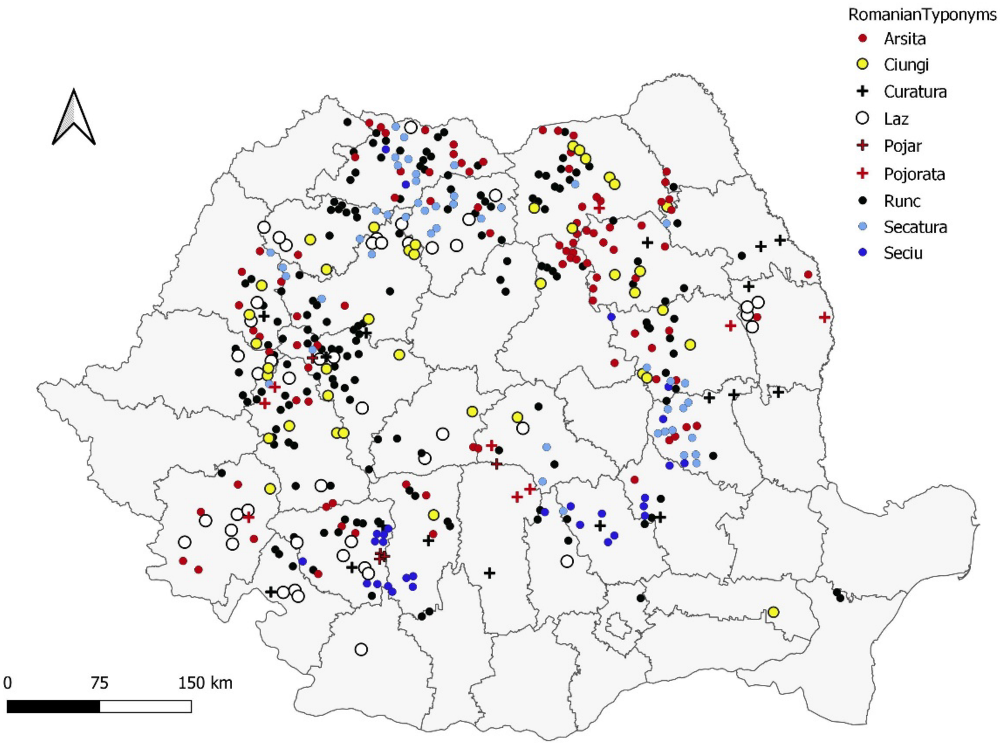


Figure 5.3. The partial distribution of toponyms related to different techniques of deforestation on the territory of Romania based on a map created by Petru Dan Idu (1997, p. 236). It can be noted that runc is one of the most widespread toponyms, being found also in the hilly areas and lowlands in Moldova and Wallachia, areas which were also covered by decidual forests until mid XIX century. Graphics by Anna Westin.

Fencing and enclosures

Another rather common category of names is related to fencing of the settlement and other land against grazing animals, because the cleared areas needed to be protected from grazing animals. Fencing has been a universal activity in most pastoral communities, for keeping grazing animals inside their pastures or outside of meadows, fields and gardens. Similar terms for fencing are found across languages. It is also common that the original term for the fence has been transferred to the fenced area. Three series of terms can illustrate this, as well as the widespread use of similar words.

The Swedish tun, German Zaun, and Old English tun means fence (noun). This term has been applied also to the fenced area as in Swedish tun, especially around the place where people live. The term for the fenced area has then been equivalent to the settlement itself, and as in old English tun, the English -ton and -town toponyms, and the Swedish -tuna place names.

The second series of terms for fencing is the old English haga, English hedge, German hege, Swedish hag and hägnad, meaning a fence. Again, the term applies also to the fenced area as in English haw, Swedish hage, Dutch haag, all denoting an enclosure, especially for grazing. In Danish, we find the similar word have and in Norwegian hage, which also means enclosure, but as in garden. The thorny shrub of Crataegus species hawthorn (English) or hagtorn (Swedish) has been used as live or dead fencing material.

Figure 5.4. Gardu Țarinii, a physical fence in the village of Lelese (Hunedoara County, Poiana Rusca Mountains) separating the village territory between pasture land and hay meadows (a two-field system moved every year).

A third example of fencing terms is the Old English to gird, meaning to fence. In Swedish we find gärde, and in Romanian gard, both meaning a fence. Corresponding terms for the fenced area are English garden and yard, Swedish gård, German Garten, French jardin, and Romanian grădină for garden. The Swedish gärde is an enclosure for arable fields and meadows.

In addition to these widespread place names indicating enclosures, there are many less widespread. One example is the -worth and -worthy names in English, from the old English worþ or worþig, meaning enclosure (Hough 2016).

The Romanian word for fence, gard is also sometimes found as a toponym designating not only a grazing exclusion from a certain area, but sometimes also a whole agro-pastoral system. As an example, Gardu Țarinii (meaning fence of the land or fence of the agricultural/productive land) is a toponym still found in some villages marking a border between the village and a certain part of the landscape used for cultivation and hay making (e.g. Forotic, Caraș-Severin county). Although there isn't any physical evidence for such a fence left nowadays, it is known that many villages involved in animal husbandry had such wooden fences separating different parts of the landscape to organize the communal grazing in certain areas in different time periods (Stahl 1998, Vuia 1975). Some villages of transhumant shepherds had three such fences (Șugag, Alba county), each family being responsible for the maintenance of portion of the fence, and some had only one called Gardu Țarinii. Most of the villages with a single fence splitting the territory in two parts, also employed a double field rotation system. One part of the village was used as pasture and the other part was used for cultivation and hay making. The following year, the land use changed the other way around, the wooden fence separating these two areas would change every year or once in two years (Stahl 1998). This ancient two fields system is still in use today in a single village in Romania in Southern Transylvania due to the will of the community, the fence separating these two areas (ţarina și pășunea) being called Gardu Țarinii (Figure 5.4). In other villages this landscape and land use feature remained only a toponym.

Placenames related to pastoralism and other agricultural practices

Many toponyms or place names are related to agricultural land-use practices. In many areas, there is a pronounced relation to current and past pastoral activities, which can be gathered from maps and from collecting information from local experts. Some of these toponyms highlight the past extent, travel routes and pastoral use of certain terrains and landscapes which, nowadays, are only integrated to a lesser extent into pastoral activities.

Historically, grazing has usually been accompanied by herding, in order to protect the livestock from predators, to avoid grazing damage to meadows and fields, and optimize the pasture use in the local territory. Several toponyms, often found in forested or mountainous areas, refer back to former herding practices.

Many mountain peaks bear the name Stânișoara (little sheepfold) and in some of these places pastoral activities are still present like in Ieud (Ivașcu 2018). The name Țarcu means enclosure or fold for grazing animals, and it is also the name of an large mountain range from the Banat area, and important place for summer grazing for several villages from that area. Țarcu Mountains are still used for short distance transhumance but in a less intensive manner then a few decades ago. Many historic but now abandoned sheepfolds are another indirect source of documentation for the intensive pastoral activities of the past.

Plai is a toponym and also a notion that describes the pastoral path used by shepherds and sheep flocks to reach the summer grazing sites in the mountains and alpine area. Thus, plai is a traditional pastoral path connecting the lowlands and villages with the summer pastures. In Maramureș, plai is a living notion still used by shepherds and locals from the area, and in Banat many place names are containing this name: Plaiu Mare (2000 m), Șaua Plaiului (2058 m), Gura Plaiului (a glade), Plaiul Fântânelor (1200 m) (Fesci & Buza 1979). In German, place- or even street-names containing the word Trift (from the Low German word drift, zu treiben) also indicate similar paths to historic grazing sites (Figure 5.5). Moreover, the word Trift is often connected with adjectives describing the type of livestock historically drifted on these paths, such as the name Kuhtrift indicating the historic pastoral path specifically for cows. There are also place names for pastures indicating the timing of the pastoral use, such as Pfingstweide, which indicates the pasture that has been usually grazed around the Christian Pentecost holiday.

In some mountainous areas, we can find certain toponyms related to mountain agriculture. In the Semenic Mountains from the Banat, there are some toponyms suggesting cultivation at high altitudes even before the colonization of German Bohemians in that area: Capu Campului (Beginning of the field), Varacica (early/summer harvests). Tomnacica (autumn/late harvests), Dealul Verzei (Hill of cabbages), Poiana cu Meri (Glade of apple trees) (Bizerea 1970) etc. Other toponyms, like Dealul Purcariului (Hill of the swine herder) (Bizerea 1970) or Purcareţ (Poiana Rusca Mountains), are considerably suggestive by their own name regarding the land use, being an area used for grazing and herding the swine herds, a practice very commonly referred to in medieval documents but extinct nowadays.

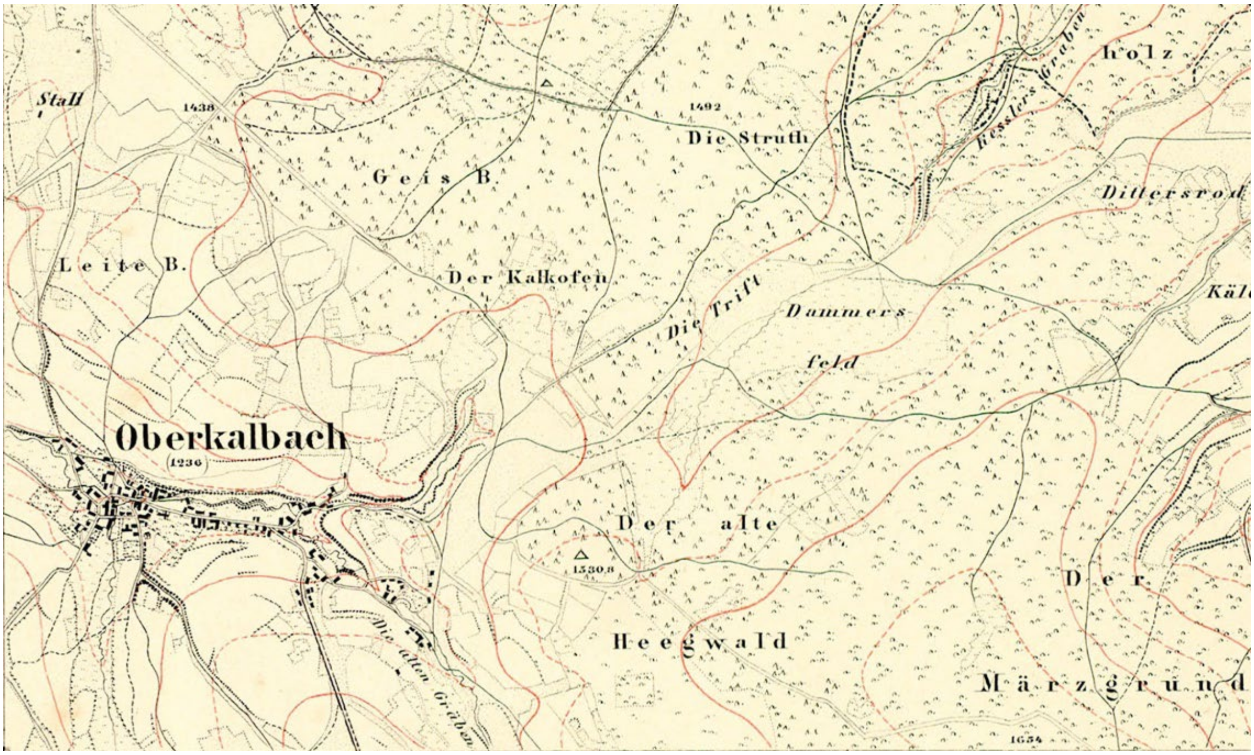


Figure 5.5. This historic map shows the area around the village Oberkalbach in the southern part of the Hessian Rhön Mountains of Germany (Map part No. 92 – Uttrichshausen). The shown landscape around the village inherits toponyms referring to different types of land uses and landscape features: Die Trift (path to a (summer) grazing site), Die Struth (thicket / swampy area), Der alte Heegwald ("old fenced forest", likely used for gamekeeping), Der Kalkofen (lime kiln) or Dittersrod (a place name with reference to deforestation).

The interpretation of some toponyms can be sometimes problematic, for example the toponyms Văratica (summery) and Tomnatic (autumnal), besides their meaning as summer or autumn harvest, might also refer to areas that can be used for grazing during that period of the year. Toponyms derived from Tomnatic were recorded 32 times and only 6 times placenames from Văratic in the historic Bucovina (Grămadă 1996).

In Southern Switzerland the toponym brusada has different meanings linked to fires or setting fire, it seems that one of its main meanings is linked to the management of common pastures. This was done by setting controlled fires to common pastures found at elevations between 1200 and 1500 m a.s.l. In order to increase productivity and eliminate unwanted woody vegetation (Conedera et al, 2007).

By researching toponyms relating to pastoral activities, we can find evidence regarding the past intensity of this activity and the territorial extension during certain periods of time and seasons, or the absence of these practices from certain areas. Usually in the past pastoral activities were more intense and extended through large areas of landscapes, even regions and countries a few decades or centuries ago. e.g., Long distance transhumance in the Mediterranean region and even in Romania covered hundreds of kilometers, from the summer grazing sites to the winter areas. Some of today's cultural landscapes with remarkable biodiversity are also the result of important pastoral practices, some of them being similar to the ones found even today in some countries from Eastern Europe (Figure 5.6).

Figure 5.6. A shepherd with his herding dog and sheep flock of the local breed, the Rhön sheep. The picture was taken probably in the first half of the 20th century near Arnsberg and Kreuzberg in the Bavarian part of the Rhön Mountains.

Place names related to man-made features of the landscape

Some place names found on maps can show us the past existence of certain structures built for agro-pastoral purposes or even temporary or permanent settlements or crafts in the landscape at considerable distances from villages or other types of settlements. These toponyms along with the land use depicted on the map can reveal the fact that landscapes were more active and dynamic some centuries ago even on a small scale. For example, German toponyms in relation to lime (e.g., Kalkofen, lime kiln), charcoal (e.g., Köhlerswiese, charburner meadow), mills (e.g., Mühlgraben, mill ditch), or stone (e.g., Steinbruch, stone pit), refer to the historic presence of remote crafting sites and crafts features.

Quite common are toponyms mentioning mills (moara in Romanian) and their owners, but particularly interesting are the toponyms related to lime kiln (Varniţa), brick fields (Cărămidăria) etc., having different distributions in different regions depending on the economic and ecological conditions (Iordan 1963, Grămadă 1996). Particularly interesting are the toponyms Dohotăria found in seven villages from historical Bucovina region, showing the existence of a past and forgotten industry, the manufacturing of wood tar from the bark of birch trees used to lubricate the axles of carts (Osachi-Costachi et al. 2015).

Toponyms related to charcoal making like Cărbunari, Cărbunariţa, Cărbunăria etc. are also found in different villages, or even some villages bear these names (over 80 village names and toponyms spread all over Romania) from the Romanian word cărbun (latin carbo, onus) (Man 1996), thus showing areas where charcoal production was a traditional practice and where locals relied on forest services. There are even some toponyms like Bocşa or Valea Bocşei, which can be translated as the places where the wood piles were erected for making charcoal (bocşă - wood pile for making charcoal).

Some ecosystems that are considered as being natural, such as some forests, could be in fact the result of natural succession of vegetation, due to the abandonment of some grasslands or temporary settlements involved in agro-pastoral activities in some areas of the landscape. For example, some toponyms like Valea Runcului in Jina (Matei et al, 1998) and other toponyms which include the name Runc (and even Arşiţa, Cărbunăria, Laz etc.) found in the Romanian Carpathians are today covered with (most probably secondary) forest.

Placenames related to vegetation types and vegetation history or animals

The existence of transformation of certain vegetation types can be discovered by specific place names. For example, the toponym Fagi translated as beech (*Fagus sylvatica*), found at altitudes below 200 m, can show us that in the past there was beech forest in that area, confirmed also by some oral histories, although nowadays the forest is made out mostly from Turkey Oak (*Quercus cerris*) and lime (*Tilia species*) (Ivaşcu unpublished data). Another example, in the Ţarcu Mountains the place name Culmea Şeroni found at altitudes of 1360 m, can be translated as The Summit of Turkey Oaks, however the main species covering that summit nowadays are beech trees (*Fagus sylvatica*).

Toponyms related to wetland vegetation are also extremely important, due to the fact these ecosystems could be still found in the landscape of a certain area or could be transformed into another type of semi-natural ecosystem or land use category. Many toponyms linked to marshes, like Mlaca or Mocira from the Maramureş region, are nowadays wet hay meadows. It is also noteworthy that the toponym Lac or Lacuri meaning lake/lakes is nowadays found in places where there are no lakes in the present, but grasslands (Ieud, Maramureş) or forests (e.g. Goruia, Banat). If such a wetland-related toponym still coincides with an actual ecosystem, then this can be considered as a case of ecological continuity solely or together with a continuity of human management. Historical maps can be used in such cases to determine the age, at least partially, to track important changes in management or the extension of such ecosystems. There are also several toponyms relating to wetlands and marshes that need to be taken into account: Rât (wet hay meadows), Lunca (river meadow), Valea (valey, riverside), Rogoaze (*Carex* species) etc.

Similarly in Germany's agricultural landscapes, toponyms with the word Acker (field) are often extended by a prefix referring to the historically often cultivated crops (wheat, turnip, cabbage etc) or are in place name connections with animals (e.g., birds, deer and hare) as well as tree species (e.g., birch, lime, beech, oak or cherry). Many toponyms in Romania also include the words Ţarina (pre-roman word, meaning productive land for both hay and plant cultivation) and Câmp (from Latin campus, meaning in Romanian both cultivated area, but it also means semi-natural grassland in many areas) (Ioniţă 1982)

It is also noteworthy that many toponyms describe exactly the main vegetation found on some mountains or hills like; Făget name found in many areas of the Carpathians meaning beech tree forest. Other similar examples are Cărpiniş (hornbeam forest), Stejăriş/Stejăret (oak forest), Frăsiniş/Frăsinet (ash forest), Cornet (areas with many cliffs where many European cornel bushes grow), Ceret/Cerişor (Turkey Oak forest) etc. Other place names might indicate other types of vegetation, in some rare cases even plants that became threatened like Dealul Colilia (Hill of feather grass, *Stipa pennata*) in the Caraş Valley.

Field observations can complete these toponyms. For example, most place names related to deforestation are found on hills and mountains within the territories of most villages and nowadays in the majority of cases the current land use is a semi-natural grassland (either hay meadows or pasture, depending on the property type).

Limitations

Misinterpretations of toponyms (the names and their meaning) is a problem one needs to take into account when doing research on this topic, or when someone is interested in including this information along with other information categories into Historical Ecology research or other projects. This is why it is necessary to consult linguistic, historic and ethnographic works on this subject. For example, some linguists might not consider the dynamic ecological information embedded within many toponyms, but it is also true that a naturalist might not see cross-cultural implications and connections to neighboring languages or language families of certain toponyms and their historical transformation (and their migration).

Limited map availability (sources and other references), limited availability of people.

Limitations regarding this kind of research might occur due to the fact that sometimes we can find a limited number of maps or references for a certain region we are interested in. Another shortcoming might be the limited availability of knowledgeable people in some cases (both time-wise and in regard to knowledge erosion), there might be cases in some communities where traditional knowledge erosion has also had an impact on the place names (e.g. the abandonment of agro-pastoral activities form certain areas of the landscape might lead to the disappearance of many micro-toponyms from the respective).

The research on toponyms relies on good quality and appropriately archived data, either in physical or digital form, when being accessible in physical resources, such as maps, books, studies, monographies etc. When it comes to digital data and other kinds of information, databases offer a timesaving tool to organize the information required for the analysis of toponyms. One example for such a database is the State Historical Information System for Hesse, Germany (LAGIS, https://www.lagis-hessen.de/en). Here, georeferenced historical maps from different time periods and a dictionary of place names are freely accessible, which facilitates the research on and use of placenames and toponyms for different disciplines. In other countries, internet databases with toponyms on a national level might not be available for the time being, but there are other databases at a local level (usually available at town halls, together with some maps). For example in Romania, the Research Institutes in Linguistics, belonging to the Romanian Academy, are working on vast collections of volumes (the format being like a dictionary) called Tezaurul Topinimic al României (The Toponymic Thesaurus of Romania) focused on all historical regions of the country, that are currently in working progress (currently only five volumes have been published related to Moldova, three regarding Transylvania and four volumes regarding Walachia). Some of the other national systems include:
China Historical GIS, Geographic Names Information System [for the U.S,], GeoNames (International), German Historical GIS, Great Britain Historical GIS , National Historical GIS [for the U.S,].

The U.S. has the National Gazeteer of the United States (https://pubs.usgs.gov/publication/pp1200USA). A final note is that these data can be integrated directly into GIS systems for spatial analysis of place names relating to current and historical land use and land cover patterns, as with the U.S. Geographical Place Names Information System (https://www.usgs.gov/faqs/what-geographic-names-information-system-gnis). Please see chapter 11 on GIS for additional details.

How place names relates to Historical Ecology

The study of place names is directly relevant to the study of Historical Ecology. Toponymy and the study of place names can be of major importance for projects and research not only in Historical Ecology, but also landscape planning and nature conservation. For example: Important information on toponyms leads directly to a new reference of historical land use, and perhaps also historical land use management. This leads to a new reference of land use continuity, which leads to an integration of such information into sampling designs for an ecological research project or biodiversity assessments if information about historical land cover and land use changes are required.

Due to the nature of the information it can contain, toponyms can highlight to researchers important processes of landscape dynamics and management, land use, vegetation structure and dynamics. By analyzing certain place names and their distribution within a landscape or within a certain geographical region, one can better understand a given landscape and its land-use patterns and dynamics through long periods of time. Toponyms might reveal not only past land use that is nowadays extinct, but also the existence and distribution of past crafts and their relation to the landscape and the ecosystems found there. However, the information embedded within place names can often be limited and might be prone to misinterpretation. Therefore, this is why researchers might gather additional information or consult expertise from specialists working in the fields of humanities (linguistics, ethnology or history) or other natural sciences (geography or ecology). Despite these obvious limitations and difficulties, certain place names that relate to land use, vegetation type and structure, traditional crafts, deforestation, man-made features of the landscape, pastoralism and other agricultural activities can complete field observations, cartography, anthropological inquiries and other methods presented in this volume. The mere survival of some of these types of place names in the memory of certain communities proves their past importance and extension and can help us to better understand the dynamic relationship between humans and their natural environment over long periods of time. We can take into consideration some of the aspects highlighted by specific toponyms also in landscape planning undertakings but also in nature conservation and protected areas management. Some of these toponyms (if there are any) might give a very important hint about the natural and bio-cultural heritage of some ecosystems and might help us understand why some current management methods need some revision.

References

Apolzan, L. (1987). Carpații - tezaur de istorie - perenitatea așezărilor respite pe înălțimi. Editura Științifică și Enciclopedică, București.

Berger, D. (1999). Geographische Namen in Deutschland: Herkunft und Bedeutung der Namen von Ländern, Städten, Bergen und Gewässern. Second Edition, Duden Taschenbücher, Vol. 25. Bibliographisches Institut, Mannheim.

Bizerea, M. (1970). Existenţa aşezărilor permanente de înălţime în Munţii Banatului, atestata în toponimia zonei Izvoarelor Timişului. Studii de Geografie a Banatului. Universitatea din Timişoara, p. 261 - 268.

Buza, M. (2011). On the origin and historical evolution of toponymy on the territory of Romania. Revue Roumaine de Geographie/Romanian Journal of Geography 55, (1), p. 23–36.

Cevasco, R. (2004). Multiple use of treeland in the northern Apennines during the post medieval period. In Ligurian Landscapes. Studies in Archaeology, Geography and History. Eds: Balzaretti R., Pearce M., Watkins C. Accordia Specialist Studies on Italy, Vol. 10. p. 155-178.

Cojocaru, V. (2014). Toponimia între istorie, geografie și lingvistică. Philologica Jassyensia X, nr. 2(20): 127-232.

Conea, I. (1993). Țara Vrancei. Geografie istorica, toponimie și terminologie geografică. Editura Academiei Române, București.

Conea, I. (2010). Clopotiva. Un sat din Haţeg. Second edition. Editura Academiei Române, Bucureşti.

Conedera, M., Vassere, S.,Neff, C., Meurer, M., Krebs, P. (2007). Using toponymy to reconstruct past land use: a case study of 'brüsáda' (burn) in southern Switzerland. Journal of Historical Geography. 33. 729-748. 10.1016/j.jhg.2006.11.002.

Fesci M., Buza M. (1979). Elemente geografice și folclorice în toponimia Munților Țarcu.Studii și comunicări III. Seria etnografie-istorie, Pp. 43-53

Filipaşcu, A. (1969). Sălbăticiuni din vremea strămoşilor noştrii. Editura Ştiinţifică şi Enciclopedică, București.

Grămadă, N. (1996). Toponimia minoră a Bucovinei. Vol. 1-2. Academia Română, Filiala Iaşi. Centrul de studii Bucovina. Editura Anima.

Homorodean, M. (1980). Vechea vatra a Sarmizegetusei in lumina toponimiei. Editura Dacia, Cluj-Napoca.

Hunn, E. (1994). Place-Names, Population Density, and the Magic Number 500. Current Anthropology, Vol. 35, No. 1, pp. 81-85

Hunn, E. (1996). Columbia Plateau Indian Place Names: What Can They Teach Us? Journal of Linguistic Anthropology 6(l):3-26

Idu, P.D. (1997). Agricultură, pădure și toponimie (Agriculture, forest and toponymy). Studia Universitatis Babeş-Bolyai, XLII, 1-2: 231-238

Ioniță, V. (1976). Note de toponimie. In: Studii și cercetări de istorie și toponimie. Eds: Răuț O., Ioniță V. Muzeul de Istorie al Județului Caraș-Severin, Reșița.

Ioniță, V. (1982). Nume de locuri din Banat. Editura Facla, Timișoara.

Johnson, L.M., Davidson-Hunt, I. (2011). Ethnoecology and landscapes. In: Anderson, E.N., Pearsall, D., Hunn E., Turner, N.(eds), Ethnobiology. Wiley-Blackwell, Hoboken, NJ, p. 267-284.

Lindholm, K.-J., Sandström, E. & Ekman, A.-K. (2013). The archaeology of the commons. Journal of Archaeology and Ancient History 10: 2-49.

Man, I.E. (1996). Valoarea informativ documentară a hărţilor cartografice pentru interpretarea interdisciplinară a etnotoponimelor şi micro-etrnotoponimelor româneşti. Marisia XXV, p. 234-290.

Matei, P., Ursan, V. & Bogdănel, D. (1998). Toponimia Comunei Jina. Centrul Județean al Creației Populare Sibiu, Editura Imago.

Osaci-Costachi, G., Cocoş, O. & Cocoș A. (2015). Old Occupations in a Sub-Carpathian Area of Romania: Cartographic Evidence from the 18th to the 20th Centuries. Revista de Etnografie și Folclor/Journal of Ethnography and Folklore. New Series 1-2: 169-193.

Stahl, H.H. (1998). Contribuţii la studiul satelor devălmașe românești. Vol I.. Second edition. Cartea românească, București.

Vuia, R. (1975). Studii de etnografie şi folclor. Vol. I. Editura Minerva, Bucureşti.

Fond prefectura judeţului Maramureş. Hărţi cadastrale, Ieud, dosar 8 (sec. 1-19): Satu Joudu in Ungaria. Comitatul Maramuresiu. Deregatoria de contribuţiune Viseulu de susu 1863.

CHAPTER 6

HISTORICAL CARTOGRAPHY

SCOTT MADRY

Figure 6.1. A cartouche from an historical map showing cosmographers at their work, from the collection of the author.

This chapter introduces the methods, techniques, and benefits of the analysis of historical cartographic data in support of Historical Ecology research. The analysis of cartographic data, and associated tabular information, can directly support this work in a variety of ways, including the creation of time series and determining spatial changes in the natural and built environments over time. Historical cartographic analysis involves several steps and techniques, which will be discussed, as well as major sources for such data, and how the maps can be digitized and fully integrated into a GIS database for further analysis and comparison with other data and analysis, as presented in chapter 11. I will also consider why we want to incorporate these data into our work. The chapter will also present some examples from our own work, including our ongoing research in Burgundy, France.

Introduction

The disciplinary underpinnings and perspectives include cartography, geodesy (the study of the precise size and shape of the Earth and how to represent this accurately on two-dimensional maps), geography, astronomy, and mathematics. The history of cartography is a fascinating story, worthy of much more detailed treatment than is possible here, but mapping our world has been of interest to humans for as long as we have wandered the landscape (Harley and Woodward 1987, Bagrow 1986). Early cartographic traditions developed independently in ancient Babylonia, China and India, but Western Europe was the source of the creation of modern mapping techniques using triangulation in the 16th century that revolutionized precise map making. There were several reasons for doing so, including exploration and colonization, the location of exploitable natural resources, military campaigns and defense, taxation, and simply the desire to know about the world and understand our relationship to it (Figure 6.2).

Figure 6.2. Military officers from the French État Major conducting field mapping using a plane table. Illustration from the cover of La France Vue Par Les Militaires, Catalogue des Cartes de France du Dépôt de la Guerre, Tome Premier par M. Corvisier-de-Villele et C. Ponnou, Arme de Terre Service Historique, Château Vincennes.

The modern cartographic revolution

Modern cartography is closely linked with the Age of Discovery in the 16th century, and the development of new techniques in mathematics, long distance marine navigation, European colonization, and, interestingly, astronomy (Turnbull 1996). Many of the first European cartographers were astronomers and mathematicians and were referred to as cosmographers at the time (Figure 6.1). The Dutch school of cartography, led at first by Gemma Fresius, was a leader in the development of modern mapping, beginning in the mid and late 1500's. Gerhardus Mercator (1512-94) was a Flemish mathematician and cartographer who was the inventor of one the most famous map projections, which is the prototype for conformal mapping still used in marine and air navigation today. In 1585 he produced a new and accurate set of maps of Europe. Later, Dutch cartographers like Abraham Orterius and Johann Lambert, took mapmaking to new heights of precision, accuracy, and, also, artistic beauty. Lambert (1728-1777) was the first mathematician to develop multiple modern map projections that accurately fit the round Earth onto a flat map plane, and his projections are still in use today (Snyder 1987).

There is an interesting connection between astronomy and the development of accurate land mapping (Edney and Pedley, 1986). One of the great astronomical issues of the 17th century was the determination of the actual shape and size of the Earth, which was much debated. Also, the distance to and size of the other planets of the solar system were major issues of the times. Determining the distance to Mars or Venus required understanding the size of our planet, and being able to make extremely precise measurements of angles across great distances, which required the development of telescopes with fine angle determination capabilities. The modern rediscovery of triangulation by Flemish mathematician and cartographer Gemma Fesius was a key aspect of making these measurements in the heavens, as well as on Earth.

Figure 6.3. The Paris meridian, running down the middle of the Paris Observatory. Image courtesy Wikipedia https://en.wikipedia.org/wiki/Paris_meridian#/media/File:Obs-Paris-meridienne.jpg

Triangulation

All maps from the 1600's (up to the very recent development of satellite positioning and GPS, as described in chapter 14) were made using the mathematics of triangulation and trigonometry, as first described in the modern era by Gemma Frisius of Flanders in 1533. This is based upon the relationship of angles and lengths within a triangle. This was also known in the ancient Egyptian, Greek, and Chinese worlds, but it was Fresius who laid the foundation for practical mapping by triangulation in the modern European era. He demonstrated that, by laying out an accurate baseline of a known length, the distance to visible features on the landscape could be determined by carefully measuring the angles, and using trigonometry to triangulate these distances. An accurate grid of triangles could then be spread across a large area, all based on the single, original measured baseline. This is the fundamental principle behind modern surveying and mapping, and the Dutch developed the first, practical methods for mapping by triangulation.

In 1669, Louis XIV, King of France, appointed the Italian mathematician and astronomer Giovanni Domenico Cassini as the first head of the new Paris Observatory, and Cassini took the work of Fresius and set about establishing what is known today as the Paris Meridian (Figure 6.3). La Méridienne de France, was established in 1720, running right down the middle of the site of the new Paris Observatory. You can see it if you visit it today.

Between 1684 and 1718, Giovanni Domenico Cassini, today known as Cassini I, and his son Jacques Cassini (Cassini ll), extended the Paris meridian north from the Observatory using triangulation to Dunkirk and all the way south to the Mediterranean Sea. This was then connected across the English Channel to London. This created a baseline that provided an estimate of the accurate shape and size for the Earth, the first determination of the size of the solar system, and also was a baseline from which the triangulation was extended east and west to all of France, laying the ground network for the new Cassini map series where the location and distances between places throughout France, for the first time, were very close to correct (Figure 6.4). The entire Cassini maps series is now available at an interactive online portal at https://www.geoportail.gouv.fr/donnees/carte-de-cassini

Types of maps and their characteristics

There are many different types and scales of maps, and they are all created for specific purposes. One of the common sayings in cartography is that 'All maps lie flat, so all maps lie'. This means that since maps are representations of a round Earth on a flat surface, that all maps must contain some types of distortion. Every map has a map coordinate reference system, defining the map projection, or how the features on the map are spatially represented on the Earth, and which defines which types of distortion were introduced. Examples are Latitude/Longitude (for very large areas) and each nation has its own national map projections(s). Maps also all contain a scale, or representative fraction, where a given length or measured line on the map represents some known distance in the real world, such as 1:50,000. So 1 cm or inch or whatever on the map is equal to 50,000 in the field. Maps are produced in many scales, ranging from 1:100,000 or 1:50,000 for regional maps, 1:25,000 for more detailed topographic map series, down to 1:2,000 for detailed cadastral maps.

All maps or map series are made for a purpose, and there are many types of maps that are useful for Historical Ecology research. These include general topographics maps, showing all of the natural and human-built features on the landscape, and also what are called thematic maps, showing one specific land use such as forest maps. geological and soil maps, political maps showing political subdivisions, military maps, transportation maps, population maps, economic maps, and many more. Cadastral maps, which are very detailed maps that show property ownership are created primarily for tax purposes for individual properties. These often also have associated tables showing who owns a specific parcel, its tax value, and other pertinent data relating to property ownership. There are several national variations, for example, in Sweden, cadastral maps were used for land redistribution between villagers, where there are two types: 1) previously common land was privatized and split between the villagers, 2) when land ownership was mixed in an open-field system (which forced everyone to work the land with the same timing) was redistributed so that each landowner got their lots in a few places instead of many. This enabled a more efficient land use and development since the individual farmer could make their own decisions. All of these maps can be of use in our research.

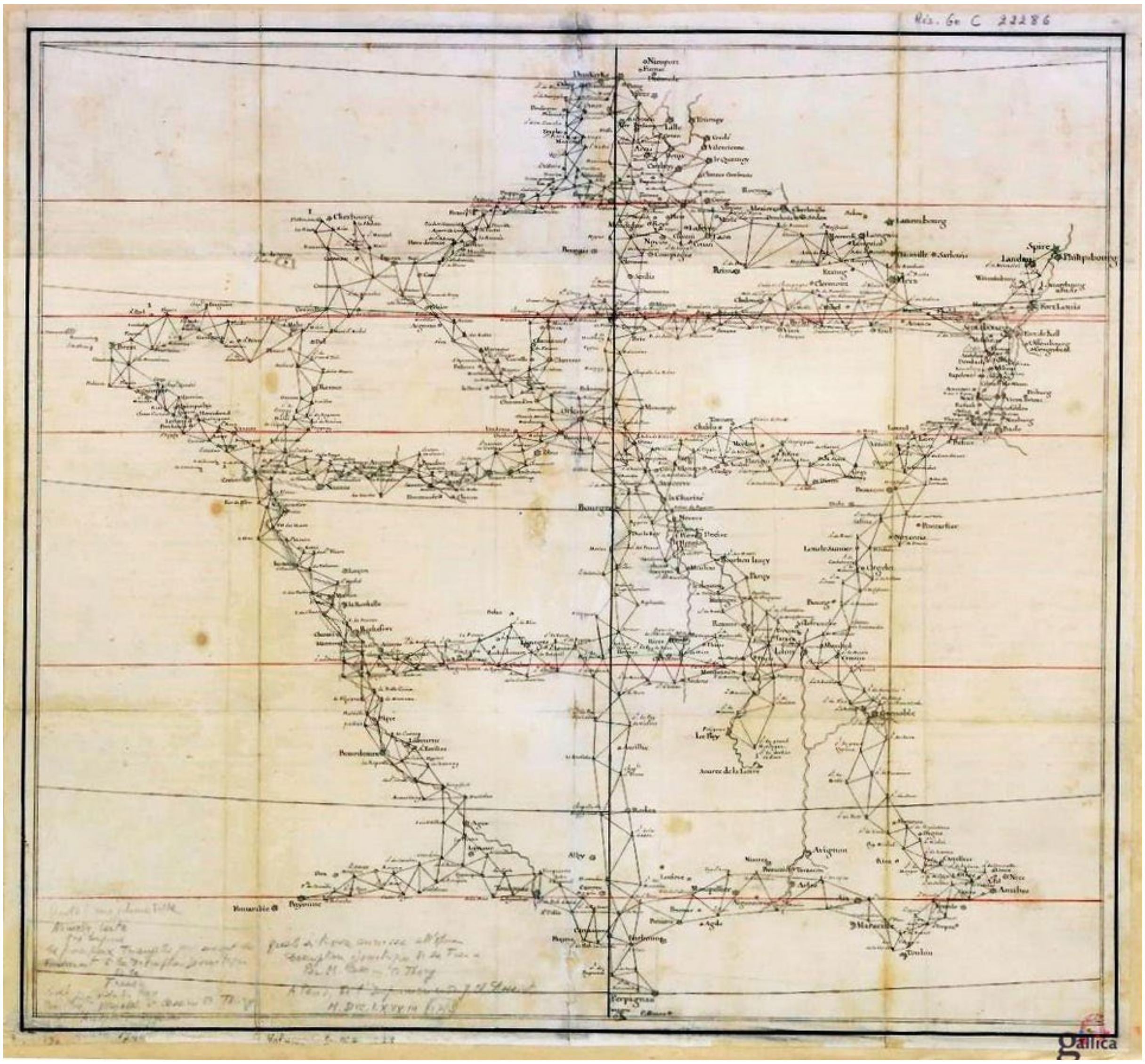


Figure 6.4. The Cassini triangulation of France. This shows the network of triangulation survey points that were collected throughout France to accurately map the entire nation for the first time, and the first in modern history. Image courtesy IGN

Historical GIS

Historical maps are now an important source of information for Historical GIS, also simply called HGIS, and Historical Ecology research (Piovan 2019). HGIS has become an important field unto itself, and several works detail the many uses of historical maps in this context (Knowles 2002, Knowles and Hillier 2008, Rumsey and Williams 2002).

Disciplinary viewpoints, perspectives, and traditions of scholarship

Cartography has always been based upon field measurements, so it is very much grounded in a tradition of both field and lab work. It incorporates field work for the creation of the map features, and also requires extensive lab data processing where all the field data are integrated onto the final map product, and then production and distribution of the final maps in paper or digital formats. This cartographic process includes basic scientific theories of geometry, astronomy, and even print making and metal etching, and also has very practical methodological components as well. It contains the scientific discipline of geodesy as an important component, as the true nature of the size and shape of planet Earth is a vital aspect of accurate mapping, and map projections all distort the map to some extent. More recently, photogrammetry and remote sensing are key components, as almost all topographic maps today are created using digital aerial or satellite imaging systems (as discussed further in chapter 12 and 13).

Basics of the use of historical cartography in Historical Ecology projects

The basic means of using historical maps in your project involves locating and processing several sets of historical maps of your study area. This can be as simple as visually reviewing old maps for interesting features and comparing them to modern maps, but today this more commonly involves the process of scanning and incorporating the data within a GIS environment, as discussed in Chapter 11. A variety of useful data relevant to Historical Ecology projects can be extracted, including changing patterns over time of land use, forest extent, property ownership, settlement patterns, transportation networks, hydrology and geological underpinnings, and political, demographic, economic, and social systems. Time series and the changes in these are possible with multiple maps, and quantitative measurements can be made, so that the total area or relative percentage of forests, for example, can be generated, thus generating useful information for our overall Historical Ecology analysis. Each map has its own representation of different features, and maps of different dates often categorize features differently, so there is much work needed to determine the best estimation of features such as forests in multiple maps of different dates and scales.

It is important to realize that the cartographic tradition varied widely around the world, and many nations have long and excellent map series while others do not. Sweden, for example, has a very long and deep tradition of accurate cadastral maps back to the early 1600's (Tomlin 1991, 2021) and the Austro Hungarian empire, which extended broadly across eastern Europe, also had detailed land use and cadastral maps that have been widely used for historical research purposes (Ostafin 2020). Other regions of the world are less well mapped across time, and each researcher must conduct a search for what maps are available for their specific area of work. It is vital to also learn about the techniques and processes used to produce each map series, as an understanding of the map's origins, errors, and biases is vital for their proper use. All maps are produced using the technology of the day, which has continually improved over time. Each map also has biases in terms of what is represented and how, so an understanding of both the technology and the intentions of the cartographer are important before they can be properly analyzed.

One of the fascinating aspects of these maps is the artistry and beauty created by the cartographers, who were called cosmographers in their day. They are individual works of art, and their makers clearly took great pride in their work (Figure 6.5). Each map had a cartouche with the date and title of the map, a dedication, and beautiful etchings and scenes of the local area or other figures. Many early maps were hand-colored and were highly decorated original works of art which were highly prized by their owners, in addition to being highly utilitarian and useful documents.

Figure 6.5. Some examples of the artwork in historical maps. From the author's collection.

Methods of collection and data analysis

The analysis of historical cartographic data can be as simple as looking at an old map and seeing what you can identify, or taking a paper copy of one out into the field and trying to see if you can identify features on the landscape. The vestiges of many historical land use and land cover features are still visible on the landscape, and Historical Ecology projects can make excellent use of these features such as fencing and hedgerow patterns, old drainage channels, abandoned dams, sections of ancient roadways, or old field boundaries. Visual interpretation of land use regimes, forest patterns, and grassland habitats are vital for the analysis of biodiversity and biological cultural heritage, as presented above. Patterns of grazing and grassland use can be extracted, and social issues relating to patterns of habitats and land use can be explored. Settlement patterns, including houses, barns, and the roads and paths that connect them with the larger community and beyond, are also very commonly analyzed through time using these techniques.

Frequently more useful, especially in larger or more long term projects, is the integration of digital maps into a GIS database, as discussed in Chapter 11. These data are also often integrated with historical tabular data such as tax records, land ownership records, and other data, as described further in this volume. But historical maps can also be used to good effect by simply viewing and conducting qualitative analysis or writing tabular data into simple worksheets.

Map scanning

This involves acquiring a high resolution scan of the map, with at least a resolution of 1200 dpi (dots per inch) if possible. Large format color scanners are widely available today. Using a smartphone or low-end digital camera is not a good option, due to the low resolution and distortions involved, and many archives now allow you to download maps that are already scanned. Once you have a digital map, you need to get all the associated metadata that you can, regarding the creators, underlying technologies, limitations, and uses. You then need to georeference the scanned image to your GIS database and project coordinate reference system, and there are many free software options available which include detailed tutorials on how to do this. Known points on the historical maps and modern data are located, and once you collect sufficient points, you can run an algorithm that will warp the old map to the new map so that it overlays your other data as well as is possible. Caution is required, as roads and rivers actually may move over time, but bridges, crossroads, and buildings are excellent choices for this process if both are represented on both the old and new maps.

Once you have your raster map properly overlaid on your GIS, you can then vector digitize each individual category of features, according to your (hopefully) well-thought out GIS data plan. So you digitize all the hydrology features, categorizing them into major streams, ephemeral streams, ponds, etc. and record the attributes into the GIS relational database. Careful consideration is called for before you digitize, as you need your data properly categorized as required to conduct your analysis. Then you do the same for roads, property ownership, vegetation, and whatever features can be identified. Quality control is vital (as the expression goes, “garbage in, garbage out”), so always have a second pair of eyes review the data before it is ‘signed off’, and fill out that metadata as well, so that it is clear who did the work using what tools. Once this process is completed, you will have a finished raster background map and all of the individual vector features extracted from the map as well. This can all be done for no cost except, of course, the time and effort required. Another option is to contract with a commercial GIS firm to do all of the work, and there are many who will gladly do so for a fee and who can do excellent and very quick work, particularly the many GIS firms now established in India. All you need is a decently fast computer, a large external hard drive, free GIS software, and, of course, the scanned maps. Once all of your maps are scanned and georeferenced, and you have extracted all of the features, you can then conduct the various statistical analysis and area measurements, time-series analyses, and visualizations of your data using your GIS, as presented below.

The WHY of using historical maps in our work

Ultimately, we need to understand why we want to go to the trouble of working with these old maps in our research. The primary purpose for Historical Ecology research is that maps from different dates provide us with a series of temporal snapshots of our study area that extends back potentially several hundred years. Each map is a unique time slice, made for specific purposes with particular technologies and goals, and we can observe our study area, now from afar, and have the opportunity to see it as it once was. By scanning, georeferencing, and digitizing the specific various land use and land cover features, we can then create time series which show us the changing nature of the landscape. We can track the ebb and flow of forest patches and agricultural fields, and also watch as the human build landscape of roads, canals, and human settlements increase or recede. All of these are key questions in Historical Ecology research, and having this allows us to put the landscape into its larger social, economic, political, and, ultimately, human context. It is not the entire picture, but it certainly is a significant part of it, especially when we have access to detailed cadastral and property ownership and tax data, it allows us to address complex Historical Ecology questions relating to humans and their environment over time.

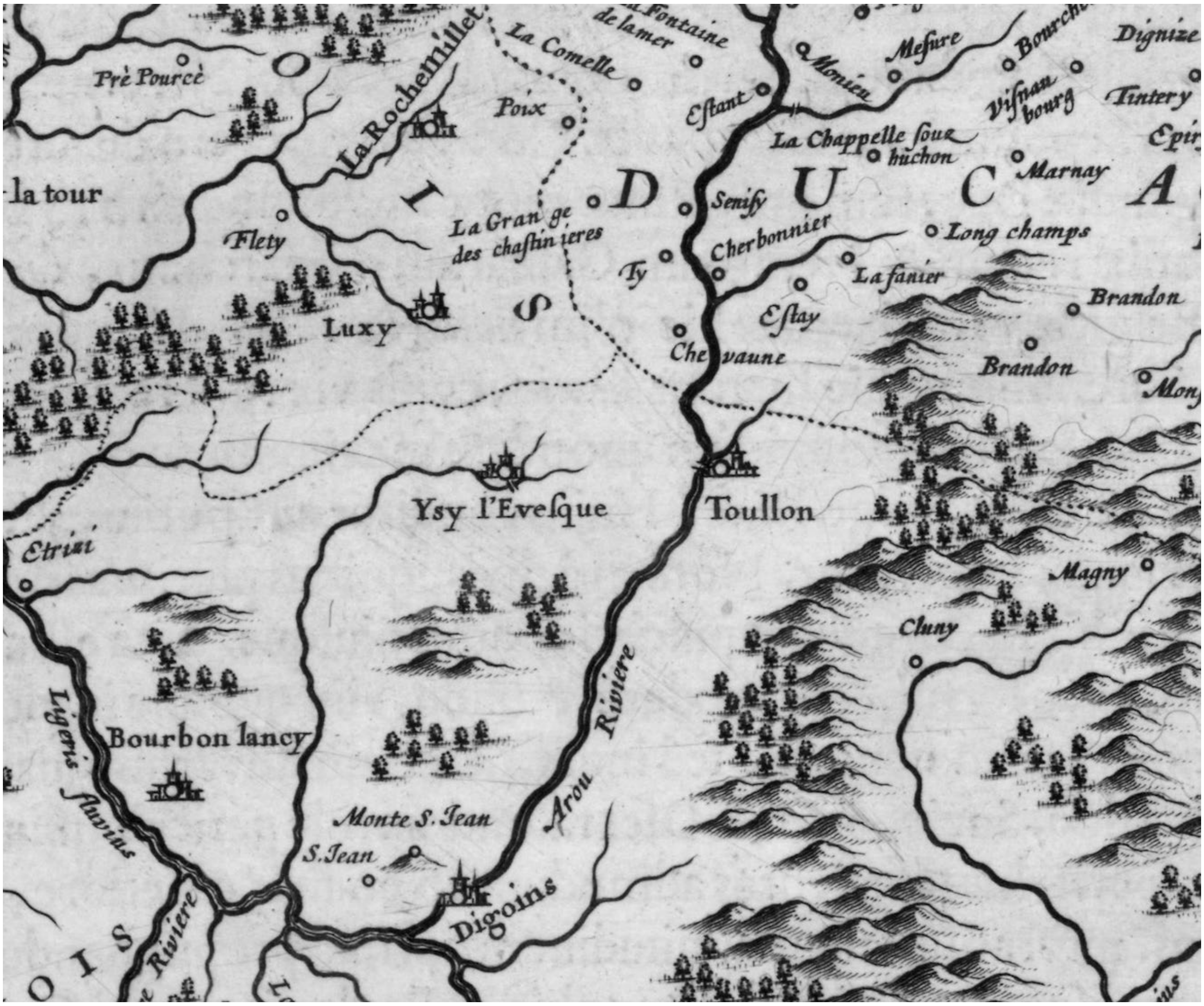


Figure 6.6. A 1631 map of Burgundy by Guiljelmum Blaeu of Amsterdam. This is a typical 17th century map, showing little detail and a simple, cartoon-type representation of features like rivers, forests and topography. Areas of forests and hills are generally located, and towns and villages have different symbols depending on their size and importance. Many of the villages and feature names vary from the modern spelling of the town names. From the personal collection of the author.

As an example, in our research in France, we have investigated the spatial patterns of water features including water mills and mill ponds and agricultural and land use, forest size, location, utilization, and the role of forests in the local agrarian economy, vines and vineyards and the ebb and flow of commercial wineries in the area, hay, pastures and fodder for animals and the changing numbers and roles of farm animals in the local economy, and the ever changing and yet consistent settlement patterns of the inhabitants, including roadways, farm tracts, railroads, bridges, ferries, and farms, villages, and towns. Each of these has been investigated individually (water, forest, vines, etc.) with a view towards the eventual holistic view of the entirety of the humans and natural landscape over 270 years. These maps, and the GIS analysis of them, are very much at the heart of our research.

Examples from our research project and study area

Over the past 45 years, the author has collected more than 65 historical maps and map series (where several maps are required to cover our study area), of our research area in France, in both paper and digital formats, originals and copies. These date back to a high resolution digital copy of the medieval Peutenger copy of the original travel map of Roman antiquity, through the 1600's, into the modern era (Figure 6.6, 6.7 and 6.8). Our earliest modern map is from 1585. Burgundy was very well mapped early on, as the Dukes of Burgundy acquired what is now the Netherlands through marriage. This was important, as the Low Countries were the focus of the new scientific techniques of cartography, as previously discussed, and they made the finest quality maps then produced, and the Dukes of Burgundy wanted their domain well mapped.

These maps were acquired for our project from a wide variety of sources, including the Institut national de l'information géographique et forestière (IGN), Archives Nationales de France, the Bibliothèque Nationale de France, the Service Historique de la Défense Ministère des Armées Archives at the Chateau Vincennes, Bureau de Recherches Géologiques et Minières (BRGM), The Library of Congress in Washington, The David Rumsey collection of Stanford University, and various regional libraries and archives in France, Europe, and the U.S. I have also acquired numerous original historical maps from various commercial dealers in France, mainly in Paris, and on the internet as well. New copies of old maps are always coming available online, and many are for very reasonable prices. Others can cost many thousands, or can only be found in museums or even in private collections which do not allow public access.

Figure 6.7. A hand-colored version of the 1759 Cassini map of our research area. This image shows our detailed study area in Burgundy, with the hillfort of Mont Dardon at the top center, forests are in green, the walled town of Toulon at upper right, with the Arroux river at right. This was the first, precise national map produced using modern triangulation methods, and is a huge improvement over all previous maps. Our study area is outlined in blue. Map courtesy the Library of Congress.

We are very fortunate to have a complete series of detailed cadastral maps and tabular data from 1834, produced at a scale of 1:2,500, which has been used to create a very detailed view of land use and land cover at that time in our project GIS (Figure 6.9). The 1834 cadastral data contains a total of 2,899 individual parcels in the commune, in an area of only 32.75 square km. The tabular tax data includes parcel size, land use, owner, tax class, tax paid, owner residence, and more.

Figure 6.8. A detailed section of the original 1823 cadastral map of the village of Uxeau, showing the individual parcels and houses and structures in red, and the same area showin in our project GIS after digitizing. Images from our project GIS by Scott Madry.

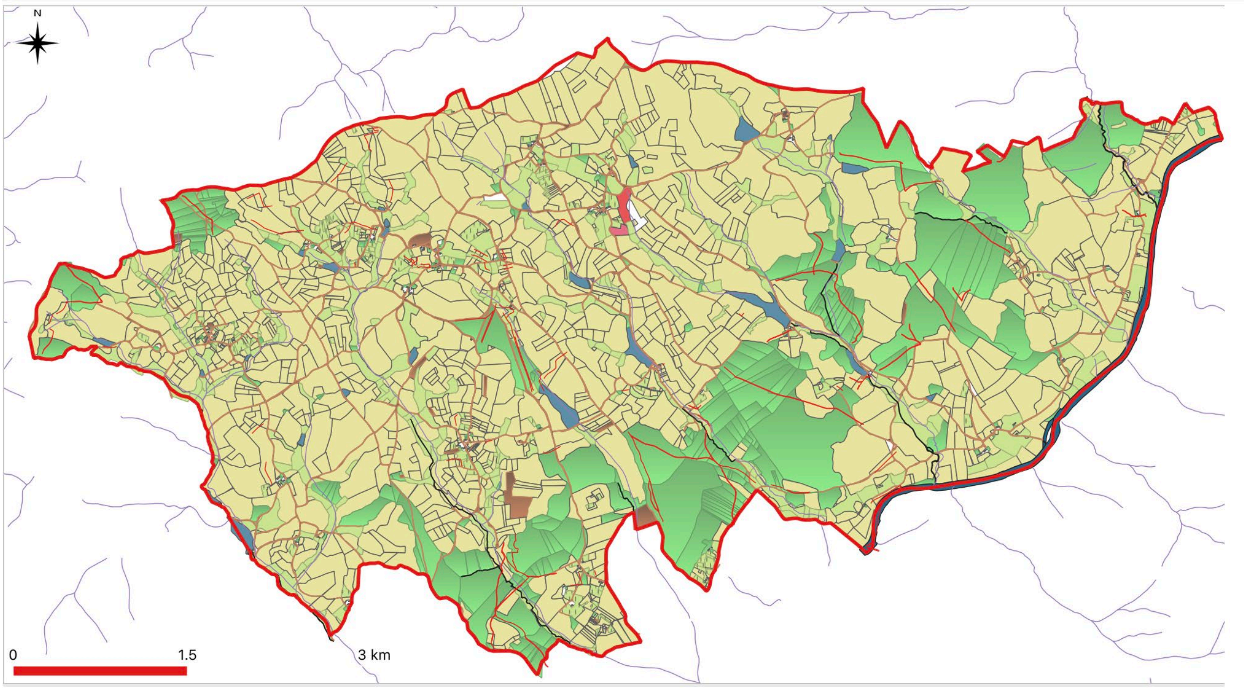


Figure 6.9. The detailed land use data from 1834, after entry into our project GIS. Forests are in green, agriculture in yellow. QGIS image by Scott Madry.

Analysis of these data show us the detailed makeup of the environment at that time (Figure 6.10).

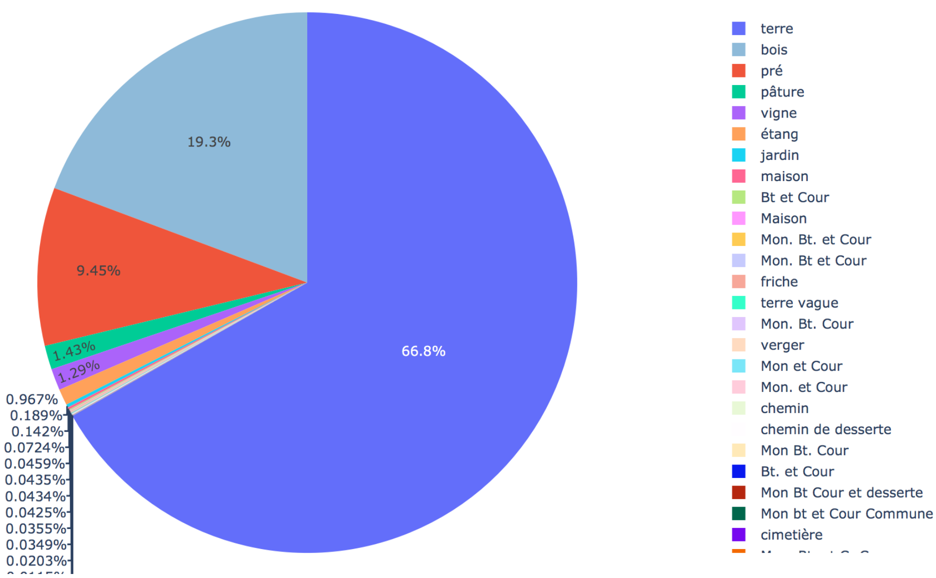


Figure 6.10. Agricultural fields make up 66.8% of the commune, with forests making up the next largest land use class with 19.3%. Meadows come next, a 9.45%, so. as you can see, 95.55% of the land is agricultural land, forest, or meadows. Pastures are 1.29, and vineyards are 1.29%. The rest are less than 1% each. QGIS graphic by Scott Madry.

This detailed dataset has been used to create a very focused view of the land use and land cover of the area at that time, including the amount and distribution of different categories, tax values, ownership, and more (Figure 6.11). This shows a single vineyard parcel in red, along with its associated ownership, value, tax class, size, and other information. We are preparing a comprehensive view of the commune at that time in terms of all aspects of the data contained here.

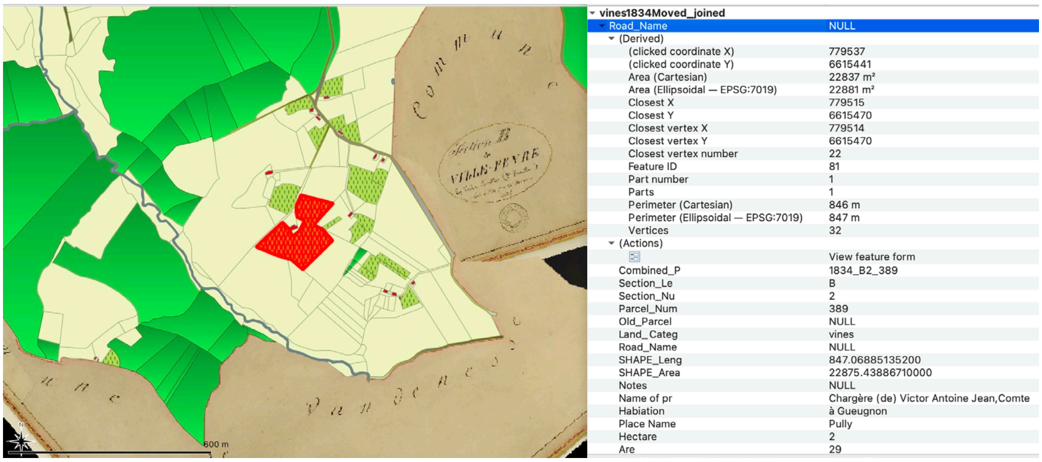


Figure 6.11. A single vineyard parcel (red) from 1834, along with the tabular data indicating the size, tax class, value, owner, owners residence, and more. QGIS images by Scott Madry. Source: Madry and Jones (in prep.)

Figure 6.12 shows the 1840 color Etat Major Carte de la France map of the area. This map series replaced the Cassini maps and was produced from 1840 through 1912 in our area. It is at a scale of 1:40,000 and we have updated versions of our area from 1840, 1848, 1889, and 1912, documenting the changes in the area on the same map series. These have all been scanned and had their features digitized.

Figure 6.13 shows the first of the modern maps of the region, produced by the IGN in 1951 using modern aerial mapping and cartographic techniques. These were the first modern maps of the region, using elevation contours and standard modern cartographic symbols and methods. These maps continue to be released frequently in scales of 1:25,000, 1:50:000 and 1:100,000.

Cartography continued to advance, and today maps are produced using digital aerial cameras and satellites, all precisely located using Satellite GNSS systems (discussed below). These are acquired on a repeating basis and, in many nations, are made freely available digitally on the internet or for a small fee in paper format.

Over the last 45 years we have collected a wide range of paper and digital maps, some originals and some copies. At present, we have a collection of some 65 scanned maps from many sources, including the various national and regional archives and libraries in France, the United States Library of Congress, commercial vendors, and other sources. We also have many paper IGN topographic maps as well. Those which were considered usable for our temporal analysis were scanned, georeferenced, and had the individual features extracted for use with our project GIS. This is a complex and multi-stage process, which is covered in Chapt3r 11. A total of 13 maps were processed in this way for use in our temporal analysis (Table 6.1).

Figure 6.13. A 1:20,000 1951 topographic map produced by the Institut National of France. This is the first, modern topographic map series in France using modern aerial photography as a source and using topographic contours (shown in brown). Forest areas are in green, ponds in blue, and structures, hedges, and field boundaries are in black. These maps continue to be produced today at 1:25,000 scale.

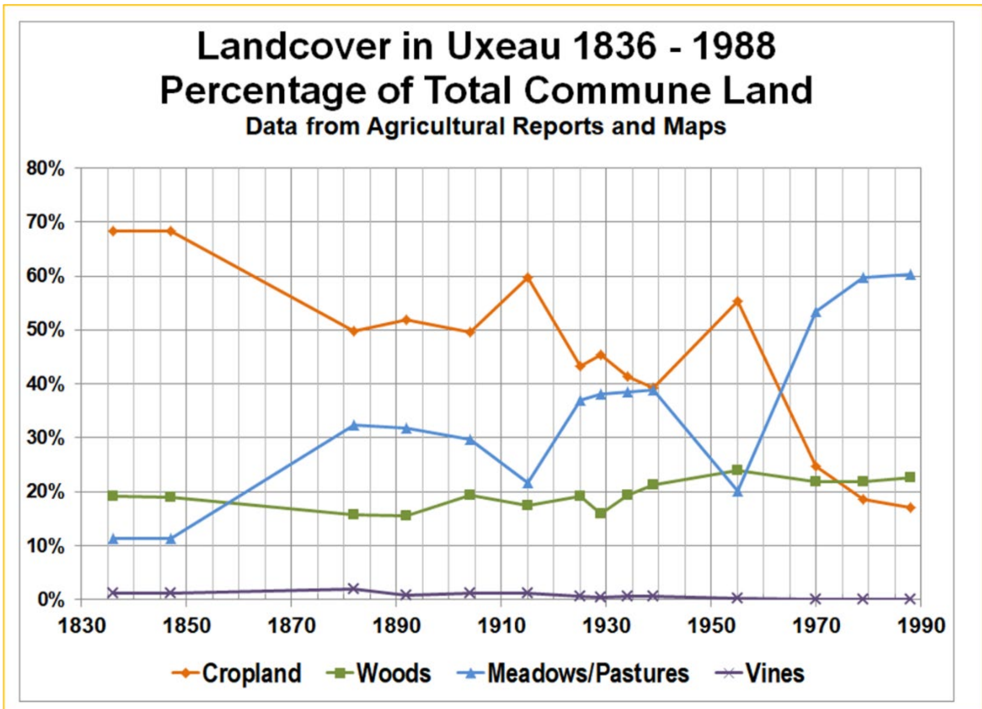


Figure 6.14. Showing the land cover in our study area, as measured in multiple historical maps and also agricultural reports. This is the vital benefit of historical maps, they produce a snapshot in time of the land use and land cover of our area, which we can digitize and measure, providing us with patterns over time. Produced by Elizabeth Jones.

Table 6.1. The 13 maps used in our spatial analysis of the changes in land use and land cover.

Year	Scale	Name	Source
1757 (field survey)	1:86,400	Carte de Cassini de la région de la vallée Arroux: carte n° 85 Autun. Map published in 1759, field surveyed in 1757	Institut Géographique National
1834 (75 years from last map)	1:2,500	Cadastre Napoleonien: Atlas cadastral parcellaire du territoire de la commune d'Uxeau, Canton de Gueugnon, Arrondissement de Charolles, Département de Saône-et-Loire	Archives Départementales de Saône-et-Loire, Archives en ligne
1840 6 years	1:40,000	Carte d'Etat Major: Autun SE carte n°136	Institut Géographique National
1848 8 years	1:80,000	Carte d'Etat Major: Autun SE carte n°136 in color	Institut Géographique National
1880 32 years	1:100,000	Carte de vegetation de Uxeau	Commune d'Uxeau Marie
1889 9 years	1:80,000	Carte d'Etat Major: Autun SE carte n°136 edition 1889	Institut Géographique National
1895 6 years	1:100,000	Carte de la France, dressée par ordre du Ministre de l'Intérieur Feuille XX-22, Gueugnon	Institut Géographique National
1912 17 years	1:50,000	Carte d'Etat Major: Autun n°136 SE et SO revisée en 1912	Institut Géographique National
1951 6 years	1:20,000	Carte de France Toulon-sur-Arroux, cartes n°5 & n°6	Institut Géographique National
1965 14 years	1:1,000-1:2,500	Cadastre feuille dressée en 1834 mise à jour pour 1964	Commune d'Uxeau
1971 6 years	1:25,000	Carte de France Toulon-sur-Arroux, cartes n°5 & n°6	Institut Géographique National
1983 12 years	1:25,000	Carte Topographique Série Bleue carte n°2826 Ouest Luzy	Institut Géographique National
2003 1 year	1:25,000	Carte Topographique Série Bleue carte n°2826 Ouest Luzy	Institut Géographique National

These 13 maps give us an excellent time series of our area from the present back to 1757 (the date of the field work for the Cassini map published in 1759). We have many earlier maps, but they are not as useful for our detailed analysis. These 13 maps (or sets of maps as our area may be covered by 4 or more maps for one date) were color scanned at high resolution (greater than 600 dpi), and entered as raster .tif files into our project GIS database. They were georeferenced to our master GIS database and modern French coordinate reference system so that features from each map series are located in the same place. Then, individual features such as roads, hydrology, forests, etc. were vector digitized as points, lines, or polygons, as appropriate, and used for our temporal and spatial analysis. These included roads, hydrology, structures, vegetation, political boundaries, and other features. Modern, detailed French vector data are now also available directly from IGN at no cost (https://www.ign.fr), but this varies country by country. You will have to search for data where you work.

Time series of the changes in vegetation cover, settlement patterns, ponds and water mills, and transportation have been created (Figure 6.14 and 6.15), including land use area measurements, as well as 3D visualizations and fly-through flights.

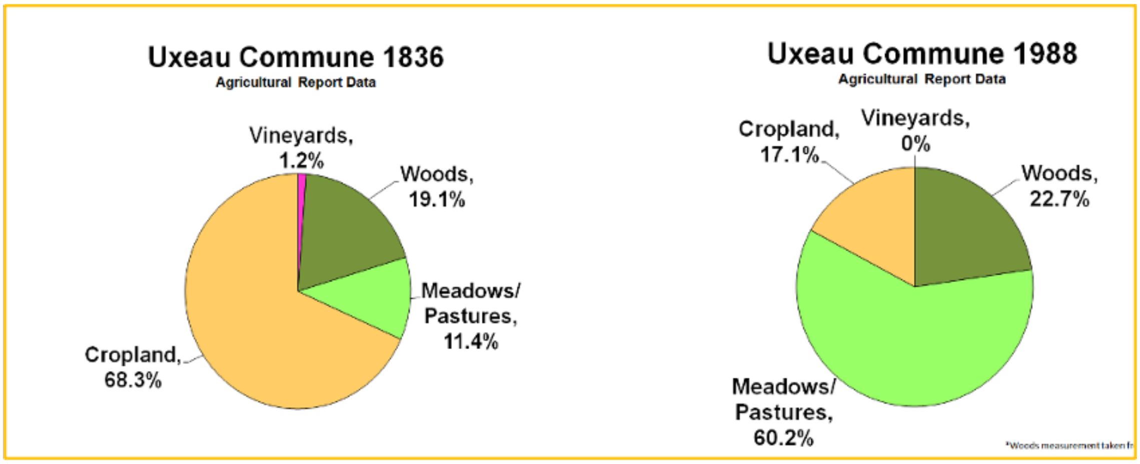


Figure 6.15. The difference in major land use categories between 1836 and 1988, based on historical maps. Produced by Elizabeth Jones.

Our research group has used these data for analysis of the Cassini map data (Madry 2006), water features (Madry et al. 2011), and working with historical maps in general (Madry 2011). Work continues on the analysis of temporal changes in forests, vines, settlement patterns, agriculture, fodder and meadows, settlement patterns and transportation in the region over time, both in specific to each individual domain as well as in an overall and integrated view (Madry and Jones 2025 in preparation). Our series of digitized historical maps are fundamental to our ability to consider the Historical Ecology questions we are addressing.

We have come a very long way from the early maps of France in the 1500's to the precise digital maps and GIS data of today. Our project has spent many decades searching for, collecting, and analyzing maps of our area to study the changes and continuity in land use and settlement in our area. We have searched map repositories, archives, academic libraries, private collections, and the internet to locate these fascinating and valuable historical resources. There are still some maps that we know existed, but that we have not yet found, and so our search continues. In the course of this most enjoyable, ongoing labor of love, we have also come to respect and admire the historic cartographers who worked so hard to map our region of Burgundy, and we marvel at the beauty and artistry of the maps that they produced.

There have been several good examples from other projects from around the world, included in several books on the subject of HGIS (Knowles 2002, Knowles and Hillier 2008, Rumsey and Williams 2002). One of the key benefits of using historical maps is their ability to be integrated directly with other data and into our GIS. So we can take historical tax and land ownership data and integrate this with our parcels, for example, to look at patterns of property ownership, tax valuation, and land use.

Limitations and Benefits

There are real limitations and benefits of working with such data. Among the limitations are the fact that first we have to locate the maps, and maps of a particular location can be difficult to find. Historical maps can be difficult to locate, and many areas of the world are not as well covered as Western Europe and North America. All maps are cultural constructs, and cannot be immediately considered to be 'true'. All maps are made for specific purposes, and are also deeply embedded in the culture, technology, and politics of the day. Some maps focus on tax values, others on natural resources or specific military needs. Many are specifically made to a given purpose, such as several maps in our region showing areas impacted by the Phylloxera vine blight. In the end, we need to understand both the technological boundaries and the social/political interests and purposes of the map makers, in order to extract the maximum amount of accurate information that they contain. So maps are both culturally constructed with the tools and abilities of the times, and all have their own specific purposes and emphasis, which drives the decisions of what is presented and what is left out. Several older maps of our region have more or less detail depending on the changing political boundaries of individual features. Some are much more accurately mapped along easily accessed roads and near towns, and much less so in mountainous areas with few roads. Clearly, the scale (or representative fraction) of the map is key for the level of detail, and time series and area measurements using maps of different scales introduces errors that are unavoidable. The wider the range of map scales, the less we can really say about the resulting analysis. Technologies and cartographic techniques such as the use of 'hatchure' to denote topography, using lines running up and down slope, were eventually replaced with modern elevation contour lines (compare Figures 6.6, 6.7 and 6,13), and all of these together make it important to understand the limitations, reliability, and benefits of each map. The many benefits of using such data are clear. We get a specific snapshot in time of the study area, which provides a window into the past environmental and cultural landscape. It is up to us to be able to understand what each map really means, and to determine what we can and cannot infer from it, and that is part of the fun of working with these historical constructs.

What we can do well and what we cannot

Historical maps are very useful for better understanding the changing nature of the natural and human-built environment over time. As stated, all maps are cultural creations, and so they also tell us a great deal about the context and technology of the map makers as well. They are less useful for 'soft' issues of interest that may not be depicted on the map, such as social, political, gender, power, family, and less obvious components of the world at that time. We should not try to infer things, or at least should proceed cautiously, when trying to infer things from these old maps.

Best practices and sources of errors and problems

First, of all, historical maps can be quite reasonably used in Historical Ecology projects using only the maps themselves, including field work and visual interpretation. There are several excellent examples of such work, including the work of our colleagues in Sweden (Weston, 2014) Historical maps have value, even if they are only copied and viewed in the lab and in the field. But the real power of historical maps is unlocked once they are scanned, georeferenced, with the land use and land cover data extracted and entered into an HGIS system.

There are several common sources of errors and problems when working with these data. First of all, there is the inevitable lack of spatial precision in older maps due to their use of the best technologies of the day, which were very poor compared with modern techniques that are now accurate to the centimeter across vast areas. Generally, maps are less detailed and less precise the older they are. Maps also vary in quality within themselves, as mountainous regions or areas that were difficult to access and survey were often less accurately presented than lowlands. Each map is a cultural construct, and it is important to try to understand the goals and intentions of the map makers (and who funded them) to better understand what may have been included and what may have been omitted. For example, some map series will show only forested areas in a single class, where others will differentiate between pine plantations and hardwood forests. Other map series, particularly topographic maps of different scales, may only show permanent water features, while others will also indicate ephemeral drainages. Some maps focus on economic interests, some focus more on accurate measurement, with only basic forest areas indicated. The purpose of the mappers (and who funded them) is an important part of using these data effectively, and to avoid potential errors in analysis by incorrectly assuming the goals and intentions of the cartographers. This also varies by individual nations, so the historical tradition of mapmaking in Sweden was quite different from France, and from Brazil, Japan, or the U.S. Older map makers generally had little understanding of modern geodesy, and so many earlier maps have great internal distortions, which also can vary across the map, with more inaccessible areas less accurately surveyed. Having information about the technology used and the fieldwork methods is very helpful.

You should become familiar with standard best practices that can help to minimize the sources of errors and problems with using these data. Rigorous georeferencing and extraction of features is key, and our group has published an improved means of conducting the georeferencing process (Madry et al. 2009). It is best to work backwards in time, from the best modern data back to the most ancient maps in turn, as these become less and less precise the farther back we go, and it is helpful to work backwards in this manner. Good records and metadata are also key aspects of producing quality data, and these should be kept, updated, and periodically reviewed.

Sources of historical maps around the world

There are many excellent sources for historical maps around the world, and many libraries and collections are scanning their maps and making them available online each year. The best place to begin your search for maps for your project, wherever it is located, is the U.S. Library of Congress, Geography and Maps division in Washington, D.C., which holds the world's largest map collection, with over 5.5 million items, and with over 56,000 maps scanned and freely available online at https://www.loc.gov/maps/. These maps are from all over the world, and range from the most recent to the very oldest maps ever produced. More are being scanned and made available each month, and all are in the public domain and free for use. High resolution scans are available for a small fee for maps not yet scanned.

The American Geographical Society library is the second largest collection in the U.S., with over 1.3 million items held at the University of Wisconsin-Milwaukee at https://uwm.edu/libraries/agsl/. The David Rumsey map collection is one of the world's largest private collections, with over 200,000 items, and he has donated the entire collection to Stanford University for their David Rumsey Map Center in the Stanford Library, including a very large digital collection accessible online. The Rumsey collection remains accessible online at https://www.davidrumsey.com as well as at https://library.stanford.edu/rumsey. The Perry-Castaneda library map collection of the University of Texas holds over 250,000 items, but with less than 20% digitized and largely focused on Texas, Mexico, and the American southwest.

And these are only the major sources in the U.S. (although they hold many international maps). All national mapping agencies, major university libraries, and national and regional archives hold varying amounts of mapping data, as well as regional and local archives, governmental agencies, and many other sources. Sadly, few of these are scanned (or even properly cataloged) at present, but this is changing and more collections are making their scanned historical maps available online, often without cost. The Biblioteque National in Paris has a very large collection and they are actively scanning their holdings, and all are now available without cost or restriction online. There are also many commercial map dealers who operate online as well, and 'new' old maps are always coming up for sale, so the search for maps is a constant process. In Sweden, there are a wide variety of historical maps now available. The National Survey Office (Lantmäteriet), National Archives (Riksarkivet, SVAR), and Department of War Archive (Krigsarkivet) have very large collections and have scanned many, which are now available on their website.

The website Old Maps Online (http://oldmapsonline.org) is a new portal that allows you to search by geographic location for historical maps in several major collections, including the David Ramsey Collection, the British Library, the Moravian Library, and the National Library of Scotland. You need to search for yourself for maps of your study area, wherever it may be. It might be best to start at Old Maps Online, and with a search at the Library of Congress Geography and Maps division website (https://www.loc.gov/rr/geogmap/), or at your national mapping agency or local university library. Your search will take you far and wide, and is something to be enjoyed… the thrill of the chase. We know and search many French map sources, including the several commercial historical map stores in Paris along the Seine river on the Quai Saint-Michel and near the Quai de l'Horloge, which was the center of French cartography for over 350 years, dating back to 1645 (Pedley 1981). 'New' old maps are constantly appearing on the market and in archives, so do not think that one look will be sufficient. Keep looking and you will be rewarded.

Cost and effort required, training needed, data size and complexity issues and software or equipment required

Getting started in using these historical maps has very little cost, as many maps are freely available. Some sites do require a small fee if new scanning of a map is required, but these fees are usually quite small. Paper copies of maps can often be purchased, but try to get the digital version at the highest possible color resolution. The tools to process these are freely available, so there is very little cost, except perhaps visiting local or regional or national archives and libraries. You may be tempted to purchase some from private map vendors, and the prices vary enormously with the market. They can be as low as a few US$ to several thousand. Some reading on the history of cartography in your study area is important, and understanding the various national or regional map series, their scales, map projections, and the purpose of the maps provides important context for your research and interpretation.

Archiving physical and digital maps

Once the scanned digital map data are in your GIS, you need to follow the same data archiving and storage process as with the other data, including proper metadata and documentation, as discussed more fully in chapter 15 on digital archiving. Proper archiving of paper maps is a very different matter. These must be stored with care, preferably in a proper map drawer, laid out flat and never rolled up, in a temperature controlled environment and always out of the sunlight, which can quickly degrade old maps. Many historical maps are very fragile and subject to fading, and require (and deserve) special care and protection depending on their condition, materials, and other factors. Important maps should not be hung on walls and exposed to sunlight without proper conservation methods.

Existing guidebooks, field guides, and tutorials

There are several tutorials available online, just look on Youtube and you can find several, including this example: https://www.youtube.com/watch?v=g-4jFTR2EC0

The University of Pennsylvania libraries has an online document for working with historical maps in ArcGIS, but it is generically useful as well: https://guides.library.upenn.edu/introtoarcgis/georeferencing

What does this have to do with Historical Ecology?

Historical maps provide us with a fascinating window into the past. Maps can provide us with a variety of excellent data for use in Historical Ecology projects, including changing patterns of settlement, land use and land cover going back several hundred years. Locating a series of maps of your study area allows you to create a time series of these, and to map the ebb and flow of land use patterns over time, integrating these with other sources of information to more fully understand the reasons behind such changes.

They are also fascinating and beautiful creations, in and of themselves, worthy of study, analysis, and proper conservation. More map repositories are making their collections available online, and the tools to fully integrate the data contained in such maps are now freely available and generally simple to learn and use using Open Source GIS tools, discussed below. The process should be approached with care and good attention to detail and best practices, but any project, from an individual researcher without funding to a much larger, multi-year funded project, should be able to incorporate these beautiful and useful data into their Historical Ecology research, and they look very nice on your office wall (out of the sunlight) as well!

To get started, the U.S. Library of Congress Geography and Maps Division can be contacted at:

Library of Congress
Geography & Maps Reading Room
1st and Independence, S.E.
Washington, D.C. USA 20540-4650
Telephone: 202-707-MAPS (6277)
FAX: 202-707-8531
https://www.loc.gov/rr/geogmap/
Ask a Librarian

References

Bagrow, L. (1986). History of Cartography. revised by R. A. Skelton. Transaction Publishers.

Connor, E. (1947). "The Cassini Family and the Paris Observatory". Astronomical Society of the Pacific Leaflets. 5(218): 146–153.

Edney, M. H.; Pedley, Mary S. (Eds.) (1986). "Cartography in the European Enlightenment". The History of Cartography. 4. Chicago and London: University of Chicago Press.

History of Cartography Wikiwand https://www.wikiwand.com/en/History_of_cartography# Accessed 2021.09.19

Harley, J. B., Woodward, D. (Eds.) (1987). "Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean". The History of Cartography. 1. Chicago and London: University of Chicago Press.

Knowles, A.K. (2002). Past Time, Past Place: GIS for History. Esri Press.

Knowles A.K., Hillier A. (2008. Placing History: How Maps, Spatial Data, and GIS are Changing Historical Scholarship. EsriPress, Redlands (CA).

Madry, S. (2006). "Hic sunt dracones (Here be dragons): The Integration of Historical Cartographic Data into Geographic Information Systems." In: Between Dirt and Discussion: Methods, Materials, and Interpretation in Historical Archaeology. Steven N. Archer and Kevin M. Bartoy, eds. Springer, New York, pp 33-60.

Madry, S. & Jones, E. (2025). "A Transdisciplinary Investigation of Continuity and Change in Burgundy, France: A Case Study in Long-Term Historical Ecology Research". in preparation.

Madry, S., Jones, E. & Tickner, A. (2009). "An Improved Extraction of Historical Cartographic Features into GIS: A French Case Study". Scott Madry, E. Jones and A. Tickner. in: Proceedings of the Computer Applications in Archaeology conférence, Williamsburg, Va. USA March 22-26, 2009. In Proceedings, and available online at: http://www.caa2009.org/articles/Madry_Contribution186_a.pdf

Madry, S., Jones, E., Tickner, A., & Murray, S. (2011). "Une Micro-Histoire de la Terre et de L'Utilization des Resources- L'integration des GIS-H (Systemes d'information géographique historiques) et des données qui y sont liées en Bourgogne du sud". in: Le Monde des Cartes, Rapport Cartographique National revue de Comité Français de Cartographie No 208, pp. 75-94, Juin 2011.

Madry, S., Jones, E.,Tickner, A. & Murray, S. (2015). Water and Landscape Dynamics in Southern Burgundy: Three and a Half Centuries of Water Management in an Agricultural Landscape" Journal of Water History 7(3):301-335.

Ostafin, K., Kaim, D., Siwek, T. et al. (2020)Historical dataset of administrative units with social-economic attributes for Austrian Silesia 1837–1910. Sci Data 7, 208.

Pedley, M. S. The Map Trade in Paris (981. 1650-1825 Imago Mundi
Vol. 33 (1981), pp. 33-45 (13 pages)

Piovan, S. (2019). Historical Maps in GIS. The Geographic Information Science & Technology Body of Knowledge (1st Quarter 2019 Edition), John P. Wilson (Ed.). DOI: 10.22224/gistbok/2019.1.4(18) (PDF) Historical Maps in GIS. Available from: https://www.researchgate.net/publication/331071936_Historical_Maps_in_GIS [accessed Sep 20 2021].

Rumsey D. & Williams M. (2002). Historical Maps in GIS. In Knowles A.K. (Ed.) Past Time, Past Place: GIS for History. ESRI Press, 1-18.

Snyder, J. (1987). Map Projections: A Working Manual U.S. Geological Survey Professional Paper 1395 U.S. Printing Office, Washington D.C. Accessed online at: https://pubs.usgs.gov/pp/1395/report.pdf.

Tollin, C. (1991). Ättebackar och ödegärden: de äldre lantmäterikartorna i kulturmiljövården. Stockholm: Riksantikvarieämbetet.

Tollin, C. (2021). Sveriges kartor och lantmätare 1628 till 1680: från idé till tolvtusen kartor. [Stockholm]: Kungl. Vitterhets historie och antikvitets akademien.

Turnbull, David. "Cartography and Science in Early Modern Europe: Mapping the Construction of Knowledge Spaces," Imago Mundi 48 1996: 5–24. Accessed at: https://www.researchgate.net/publication/249029092_Cartography_and_Science_in_Early_Modern_Europe_Mapping_the_Construction_of_Knowledge_Spaces

Westin, A. (2014). Att tyda landskapets berättelser - En metod att tolka biologiskt kulturarv. Riksantikvarieämbetet.

SECTION 3

METHODS IN HISTORICAL ECOLOGY

This section presents four of the most commonly used disciplinary methods that are used in Historical Ecology research. We begin with Ecological Ethnology and Ethnobotany, which provide significant ecological information for our research. The second chapter covers archaeology, specifically landscape and historical archaeology. Archaeology is a broad and deep discipline, focusing on the material remnants of human cultures and activities, and archaeology can provide us with a deep column of information reaching far into the past. Third, we look at the role of museums and museum collections, and finally, we consider engaged Historical Ecology research. Together, these disciplinary perspectives and the data and insight that they provide to us are some of the key foundations for Historical Ecology research.

CHAPTER 7

ETHNOBOTANY

THE ACADEMIC STUDY OF OUR RELATIONSHIP WITH PLANTS

HÅKAN TUNÓN, ANNA WESTIN, COSMIN IVAŞCU

Plants are a part of our everyday life and have always been. Ethnobotany is the study of the complex relationship between humans and the plant world found in their surroundings. This discipline has a long history of academic research all over the world. Ethnobotanical research includes the use of plants in all aspects of life, e.g. specific customs, religious beliefs, food, medicine, fibres, and other cultural or economic aspects. The use of certain species of plants can give important information on the complex interaction of people and plants in the past, the present, and the future. In some cases, even the linguistic analysis of specific local plant names can be used to inform us about past land use or specific vegetation features. This chapter provides an overview of ethnobotany and how ethnobotanical work can be done, also referring to central handbooks on the subject. We explain some of the most important methods on how to study ethnobotany in historical contexts and in present communities, including different kinds of interviews. The chapter also highlights the importance and contributions of ethnobotany in undertakings based in Historical Ecology by gaining additional information on local communities in past and present.

Introduction

From the beginning of time, humans have used plants for a multitude of purposes. It is therefore fair to say that the knowledge about how to use and relate to plants is as old as humanity itself (e.g. Figure 7.1). A central concept in ethnobotany is traditional ecological knowledge (TEK), defined as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. As a knowledge–practice–belief complex, traditional ecological knowledge includes the religious traditions of a society" (Berkes 1993).

Ethnobotany is the academic discipline studying traditional ecological knowledge and the complex relationships between people and the plant world, including the nomenclature, use and beliefs surrounding them, in past and present communities. Ethnobotany provides insights into people's use of plants as basis for material culture, for food, medicine and other physical needs. It also informs about intangible aspects, the practical methods used, how people have taken care of significant plants, and their role in customs, beliefs and spiritual practices (Figure 7.2.). Plant knowledge and practices in local communities may have been transmitted between generations, but can also have been learnt from books or from people outside the local community. Therefore, ethnobotanical studies may also inform about social and cultural influences and conditions outside the local setting.

Figure 7.1. The ability to gather food and to find water is one of the oldest needs of humankind. Plants could of course be eaten directly, but also help people in hunting and finding water. The left picture shows the reconstruction of the only known complete Saami bow made from the combination of *tjurved* ([bull's wood], compression wood, the harder underside of a coniferous tree that has grown leaning on one side) and willow (*Salix*), put together with glue made from bones of perch (*Perca fluviatilis*), and wrapped with bark from birch (*Betula sp.*). Note the Iron tip and ring on the bottom which makes the bow useful as a ski pole for cross country skiing. The right picture shows the fountain apple moss (*Philonotis fontana*) growing in water springs. Its pale green colour stands out in the vegetation. One of our first ethnobotanists, Carl Linnaeus, noted on his Lapland journey that the Saami people used the moss as a guide to find cold springs where they could store food.

The subject has several interdisciplinary and intellectual origins, within both natural and social sciences. Ethnobotany can broadly be described by the two parts of the term, where "ethno" implies the study of people, and "botany" the study of plants. Between them lies a wide spectrum of research angles ranging from archaeology and history to natural product chemistry and bioengineering of new crops, but with a focus on relationships between people (and communities) and plants. Ethnobotany makes important contributions to Historical Ecology and other scientific endeavors based on both natural and social sciences, such as conservation biology and ecological restoration, political ecology, linguistics, cultural ecology, environmental ethics, nutrition and pharmacognosy (Nolan & Turner 2011). Where many other historical ecological disciplines grasp over-all perspectives of people-nature interactions such as general land use, ethnobotany contributes with in-depth knowledge about intimate interactions between humans and ecosystems.

Figure 7.2. Harvest of birch bark in a young tree stand in Värmland, Sweden (around 1900). Ethnobiological aspects of using birch bark includes the tangible objects made from the bark, as well as intangible knowledge about the harvest and crafting of for example baskets, bags, and roofing. Note the boy holding a wooden flute which in Sweden is traditionally wrapped in birch bark. Acknowledging the importance of birch bark in people's lives raises awareness about past livelihoods, the importance of the tree species for supplying enough bark for roofing, may also lead to the search of traces from old peelings (which constitutes a biological cultural heritage). Photo: A. Aurelius.

Historical perspectives on ethnobotany

Ethnobotany can be considered a very old discipline with a tradition over millennia (referring to people's knowledge and relationship with plants) or fairly new, slightly over a century old (referring to the scientific study of people's relationship with plants; Schultes & von Reis 1995, Albuquerque et al. 2017). Researchers, adventurers, travelers, merchants, and others have always collected knowledge concerning local uses of different organisms, with the intent to spread the use to new areas or to find novel uses. Many of the ancient civilizations had written documents about plant use, e.g. in Sumerian, Egyptian, Assyrian, Vedic and Chinese medical manuscripts (Balick & Cox 1996; Svanberg & Łuczaj 2014). Ancient Greek and Roman authors documented their knowledge of plant use as well as the uses by neighbouring civilizations. From ancient Greece, approximately 78 vernacular plant names from the Dacian language were recorded, found in Pseudo-Apuleius and Vienna Dioscorides botanical works from the 4th and 6th centuries, respectively (Bocşe & Mihaiu 1995). Such documentation of vernacular names is of linguistic importance and helps us understand more about the extinct ancient languages from Dacia and neighbouring tribes. One of the most complex writings regarding the traditional plant use in Ancient Rome is Pliny the Elder's Natural History (*Naturalis Historiae*) from the first century AD, especially in the books XII-XXVII (Pliny 1855–1857; available in English https://www.gutenberg.org/ebooks/author/50041). In Europe, mediaeval herbalists continued the tradition dating back to Greco-Roman antiquity regarding the use and knowledge of medicinal plants (Svanberg & Łuczaj 2014). Carolus Clusius (1526–1609) is considered one of the most important late mediaeval Western botanists and during his travels he collected considerable information of the folk use of certain plant species from different areas of Europe (Svanberg & Łuczaj 2014). During Carl Linnaeus travels through different Swedish provinces in the 18th century, he collected information about the national flora and fauna, natural resources and people's knowledge about them (Balick & Cox 1996; Tunón 2015). In 1749, Linnaeus published his utilitarian Flora oeconomica, the domestic values of wild plants growing in Sweden, a forerunner of the 19th century subject "economic botany" (Figure 7.3).

The term "ethnobotany" was coined 1895 in a lecture by the American botanist John William Harshberger, dealing with the use of plants by aboriginal peoples. Harshberger also pointed out ethnobotanical studies as potentially useful for "suggesting new lines of manufacture" (Harshberger 1896), an example of a line of thinking that has been and still is the background to many studies. Other terms used to describe the relationship between local communities and the surrounding flora were for instance "applied botany", "aboriginal botany", "botanical ethnography", and "plantlore" (Clément 1998).

During the 19th century linguists, ethnologists, and folklorists, as well as botanists, and natural historians studied local plant use and plant folklore in many European countries (Tunón 2015). Ethnobotany as a more scientific subject started to develop in Europe before and especially after the Second World War, by folklorists and other social scientists like Heinrich Marzell (1885–1970), Eugène Rolland (1846–1909) and other pioneers (see Svanberg & Łuczaj 2014). There have also been highly developed, national ethnobiological traditions in different countries, rather unknown outside of its national borders, because most of its research was published in the native language.

The academic subject developed further by scholars in the tradition of economic botany (North America). As ethnobotany became a subdiscipline of anthropology during the 1950's, American ethnobotanical research shifted from the study of solely utilitarian use of plants to the recording of vernacular plant names and the classification (folk taxonomies) of plants within indigenous cultures (Ford 2011). In 1955 the Society for Economic Botany was formed (the society changed its name in 2022 to the Society for Ethnobotany). There was also an increased interest in ethnobotany from the botanical perspective during the 1980's and 1990's due to bioprospecting from the pharmaceutical industry as well as the processes that led up to the UN Convention on Biological Diversity in 1992. The International Society of Ethnobiology was founded in 1988 and the International Society of Ethnopharmacology in 1990.

According to the American anthropologist Eugene S. Hunn (2007), ethnobotany has gone through four stages, referring to an increased awareness and gradual increased inclusion of local people. The first stage focused on the recording and listing of names and uses. A second stage (cognitive ethnobiology) applied cognitive, linguistic, and cultural theories on ethnobotany. During the third stage (ethnoecology), traditional knowledge and practices were fused with ecological anthropology, and the fourth stage (Indigenous ethnobiology) developed a more active participation of the local communities themselves in science (see also Cotton 1996). Ethnobotany has also developed during the last century, from descriptive documentation to more multidisciplinary and analytical (e.g. Anderson 2016). Another historical review of ethnobiology (including ethnobotany) and its various epistemological frameworks is given by the Catalan biologist Ugo D'Ambrosio.

Ethnobotany is part of the wider disciplinary context of ethnobiology. Ethnobotany, and other sub disciplines of ethnobiology (such as ethnozoology or ethnoecology), can be approached from a multitude of different scientific disciplines; ethnology, anthropology, archaeology, history, biology, medicine, and indigenous peoples' rights, just to mention a few.

As mentioned, ethnobotany is a vital part of TEK, and can therefore serve as a foundation to study other aspects of TEK, including landscape management, social institutions, and worldviews (Berkes 2008, see Figure 1.1, Page 17). Ethnobotany helps to grasp the significance of various plant species within the context of local culture and to identify cultural keystone species.

Figure 7.3. Carl Linnaeus (1707–1778), the "father of botany" was also an ethnobotanist. During his travels, among many other things, he collected information about the use and value of plants growing in Sweden. His work *Swedish flora*, beside the descriptions of the plants and habitats, also contains information about how the plants have been used and some local names. A section from the famous portrait of Linnaeus in Saami clothes by Martin Hoffman from 1737.

Changing ethnobotanical knowledge

Traditional ecological knowledge, including ethnobotanical knowledge, is being transmitted from person to person, from one generation to the next, with possible innovation added by each generation (Berkes 2008). This knowledge is adaptive, it is constantly changing in relation to the needs of people. Practices in use will be preserved and developed in its social-ecological context, while knowledge which is no longer needed, will fall out of use, erode and eventually be forgotten (e.g. Axelsson Linkowski et al. 2017). Elements of knowledge may also be preserved ex situ through documentations made by researchers, other visitors or by the users themselves. However, the practical knowledge, the unspoken and context-dependent understanding is difficult to fully record in writing and the documented knowledge is "frozen" in time. Documentations represent snapshots of the conditions at a certain moment affected by the situation at the time. Still, documentations made by travelers and others are invaluable sources to knowledge that otherwise would have been completely forgotten.

Ethnobotanical knowledge does not only come from intergenerational transmission, neither in historical contexts nor in current day rural communities with traditional lifestyles. The flow of information via people and literature has therefore been mixed with knowledge derived from experience-based local knowledge. One important source of knowledge transmission is literature and magazines. In Europe, information from classical literature and other scholarly books has been widely spread in the society, implying that even very old rural practices and perceptions may be based on external influences. With time, the availability of books and magazines has accelerated the spreading and influence from "non-local" information on local traditions. At times, new uses of plants have been intentionally introduced, for example during times of famine with an increased need to utilise local food sources. Several waves of interest in "traditional" plant knowledge during the last century have contributed with this spreading of knowledge. In southeastern Europe, books are still owned by a few people and subjects of prestige and respect among the rural communities (Leu 1996). People with access to books are prone to pick up knowledge from them, however plant names and uses learned from book are not necessarily widely spread among the people in the community that don't have access to these books.

Knowledge acquired from books, magazines or other sources outside the community (or the region), can indeed be traditional and experience-based by the nature of their information, but it may originate from a different area or even country than the studied community and far back in time (Figure 7.4.). It is often difficult to distinguish between different sources of knowledge, but it may be important for example concerning local plant names or medicinal or other plant uses. Similar reflections have also been made regarding the situation of the origin of plant knowledge in Sweden (e.g. Tunón 2005).

Foreign influences may be revealed by plant names. In Sweden, St. John's wort (*Hypericum perforatum* and *H. maculatum*) is called johannesört (in analogy with many other languages). The name was imported from Germany many centuries ago and refers both to the red pigment in the flowers ('the blood' symbolizing to the decapitation of John the Baptiste) and that the flowering starts around St. John's eve, around 21 June. However, prior to climate change, the flowering in Sweden started approximately a fortnight later and therefore the connection between the name and the flowering date is not particularly logical for Swedish conditions. Another vernacular name for St. John's wort is/was hirkumpirkum, a misconception of the Latin name of the genus.

Hunn (2007, cf. Balée 1994:164–165) mentions "the divide between communities rooted in the land and those caught up in our contemporary global flows of capital, labor, and commodities", meaning that communities with more traditional lifestyles and stronger dependence to local biological resources are suggested to have a closer relationship with nature and its inhabitants and therefore a more extensive traditional knowledge, than most of us. Currently, there is an increasing interest among people in general on how to identify, harvest and use wild plants for food and medicine, and information is spread via numerous books and influencer accounts on social media, which contributes further to the spreading of ethnobotanical knowledge.

Figure 7.4. A local expert on medicinal plants from the village Solcani from the Republic of Moldova. Combining both traditional local knowledge and information from magazines and media, she cultivated most of the medicinal plants in her garden, but also collected some plants in the landscape surrounding her village. Photo: Cosmin Ivaşcu.

Ethnobotanical textbooks

During the past decades there have been numerous useful textbooks published in the field of ethnobotany and the authors have taken different angles in order to introduce the subject and possible research perspectives. Mostly they provide examples on how dependent we are on plant resources for all kinds of reasons. Here we mention a few renowned and useful books (in chronological order).

Schultes, R.E. & Von Reis, S. (eds.). 1995. Ethnobotany: Evolution of a Discipline. Dioscorides Press, Portland, USA.

This anthology with over 40 authors and 37 chapters reflect over a wide range of different perspectives on ethnobotany. The chapters are divided in units, e.g. socioethnobotany, historical ethnobotany, ethnobotanical conservation and ethnopharmacology. The book has a fairly strong focus on practical aspects of ethnobotany to evaluate traditional uses and their potential role in local health, drug development, landscape governance, policy planning, etc., to a large extent a continuation of the historical perspective of utilitarianism. The chapters serve as well written examples to inspire future works. However, the book does not deliver much practical methodology in general terms.

Balick, M.J., Cox, P.A. 1996. Plants, people, and culture. The science of ethnobotany. Scientific American Library, New York.
The book is an overview over human dependence on plants in six chapters. There are many examples of medical drugs of plant origin that have been derived from the knowledge of local peoples. Naturally, there are also stories and reflections related to other kinds of plant use and even aspects of ethnobotany's role in nature conservation. Like the previous book, this is a book for inspiration rather than one of methodologies. There are some practical lessons to reflect upon, for instance, the authors state that ethnobotanist need to be "able to step for a time completely out of their own cultures and embrace the indigenous worldview as a new reality". The authors state that "modern ethnobotanists adopt the role of participant-observer, living with the people under study, observing their daily life and customs, and learning about their lifestyle, foods, disease systems, and myths and legends. In true participatory ethnobotany, the indigenous person becomes a teacher, a colleague, and a respected and valued friend" (p. 42).

Cotton, C.M. 1996. Ethnobotany: principles and applications. John Wiley & Sons, Chichester – New York – Brisbane – Toronto – Singapore.
This book delivers an introduction to the history of ethnobotany as a subject and a valuable table over how different people have defined the subject through the years from 1873 to 1994. This gives insights into what have been considered as the main focus of the subject by different researchers and how to, at least hypothetically, draw the border to, for instance, economic botany. It also covers how the subject has broadened, from first and foremost studying the practical use of plants, to also include beliefs of all kinds. Cotton also describes elementary botany and phytochemistry in order to better understand traditional botanical knowledge. She mentions that ethnobotanical studies have departed from three different approaches; utilitarian ethnobotany (in order to find useful plants), cognitive ethnobotany (including also cultural and social aspects of plants), and the ecological/cultural ecological approach (human activities are dependent on the ecological surrounding, and the other way around). One chapter of the book specifically reflects on methods for ethnobotanical studies. Since multidisciplinarity is seen as a strength of the subject, the methods depart from several different research disciplines. The second half of the book is a parade of different examples of ethnobotanical studies with various angles and experiences that provide food for thoughts for future studies.

Höft, M., Barik, S.K., Lykke, A.M. 1999. Quantitative ethnobotany. Applications of multivariate and statistical analyses in ethnobotany. People and plants working paper 6. UNESCO, Paris.
This is a relatively narrow working paper that presents a number of multivariate and statistical methods for the analysis of ethnobotanical data. The aim is to enhance the indicative value of ethnobotanical studies; to make qualitative studies more quantitative. Ethnobotanical data could, through different kinds of statistical methods, be interpreted in a way that more objectively shows different patterns, e.g. relative importance of different plant genera, preferences, and quantitative impact on the ecosystems.

Cunningham, A.B. 2001. Applied ethnobotany: People, wild plant use & conservation. Earthscan Publications, London & Sterling, VA.
This book is a manual for ethnobotany. It begins with an overview over local people as ecological factors and how flora are shaped by humans, followed by reflections regarding participatory working methods for vegetation inventories. A collaboration with the local people needs to be based on the right methods on a case-by-case-consideration. Consequently, it reflects upon, for instance, when a Participatory Rural Appraisal-

method (PRA) is advantageous over interview methods, how to design a questionnaire, or relevant botanical techniques. It discusses pitfalls when it comes to nomenclature, scientific versus ethnotaxonomy and so on, as well as how to analyse the local market using a checklist for ethnobotanical surveys. It also provides techniques for assessing availability of plant resources, for example how to measure heights of standing trees, in order to estimate sustainability of harvesting. Furthermore, it describes how aerial photographs and satellite images can be used to determine land patterns to compare with the results of participatory mapping. There are vast amounts of insights collected in relatively dense texts that inspire practical work.

Martin, G.J. 2004. Ethnobotany: a methods manual. Earthscan, Oxon, UK. & New York.
This book (first published in 1995 and revised in 2004) is an appreciated manual with practical recommendations and that also benefits local communities. The book consists of eight chapters; data collection, botany, ethnopharmacology, anthropology, ecology, economics, linguistics, and finally ethnobotany related to conservation and community development. It covers the six main disciplines in ethnobotany and provides extensive reflections regarding methodologies in all of these areas. The book is filled with examples and case studies to inspire the reader to design a future project. Participatory Rural Appraisal (PRA) is for instance described as a time efficient way of data collection. Martin also highlights that ethnobotanical data can consist of many different materials, e.g. interviews, photographs and plant material, which makes it necessary to consider how to construct a relevant database.

Albuquerque, U.P., Ramos, M.A., Ferreira Júnior, W.S., de Medeiros, P.M. 2016. Ethnobotany for beginners. Springer briefs in plant science. Springer, Cham, Switzerland.
A relatively easy textbook aiming to help beginners "interested in a quick and pleasant read". The authors state that the keyword is "reflection". With reflection, an ethnobotanist can start to understand people's relation to plants, the interaction of nature and culture described as biocultural diversity. They stress that ethnobotany is the recent science studying the ancient relationship between people of living cultures and plants. Hence, they consider studies of past cultures as archaeoethnobotany or paleoethnobotany, and the methodologies used differ. The ethnobotanist's academic background will focus on the people's knowledge from different perspectives. When ethnobotany departs from botany it often focusses on listing useful plants. When it departs from anthropology it seeks the understanding the role of plants for the culture, while an ethnoscientific approach focus on how the people themselves understand their plant knowledge and culture, for instance when it comes to ethnotaxonomy. The authors argues that the way forward is interdisciplinarity. Chapter 4 focuses on investigation methods and highlights methods like individual interviews, participant observation, free listing, participatory methodologies, and triangulation techniques. They conclude the methodology chapter with some recommendations, e.g. "treat informants as expert of the subject, as they truly are, since they possess knowledge of phenomena that are unknown to us…".

Tunón, H., Dahlström, A. 2010. Nycklar till kunskap. Om människans bruk av naturen. "Keys to knowledge. About human use of nature". Centrum för biologisk mångfald, Uppsala.
We would like to mention a book that is of limited accessibility to many readers since it is published in Swedish, but that has a perspective that differs from the previously mentioned one.

As several of the other books it is an anthology and, even if it is meant as a textbook in ethnobotany/ethnobiology and agrarian history, it is not written by ethnobotanists. It is a multidisciplinary book with chapters focused on methodologies dealing with different sources that can provide information for ethnobotanical studies. Consequently, the 33 chapters of the book includes how to work with archives, farmers' diaries, plant names, written sources, artefacts, paintings and photographs, historical maps, interviews, participatory ethnographic mapping, inventories of biological cultural heritage, archaeobotany, palynology, osteoarchaeology, and dendrochronology. Hence, the book provides an introductory palette on a wide range of examples of methodologies that can provide valuable information or be used for triangulation to verify other data. We will summarise and use reflections from this book in the methodology section of this chapter.

Anderson, E.M., Pearsall, D. M., Hunn, E. S., Turner, N., J. (eds). 2011. Ethnobiology. Wiley-Blackwell Inc., Hoboken, New Jersey, USA.
Although it is not solely focused on ethnobotany, this book is a must read and one of the best synthesis on ethnobiology that includes besides ethnobotany, also ethnozoology, ethnomedicine, and other ethnosciences. The authors start with the intellectual origins of this emerging discipline and embedded subdisciplines, discuss the current state of ethnobiological research all over the word and their importance for ethics, conservation science or historical ecology. One chapter deals exclusively with the development of ethnobiology in Europe. Three chapters focus only on ethnobotany and specific problems related to endeavours focused on the study of humans - plant relationships also from a historical perspective. Chapters 10 and 11 deal exclusively with reconstructing ancient subsistence patterns through the use of botanical remnants in archeological findings.

How to do ethnobotanical research

Ethnobotany is generally considered a "discipline located at the intersection between natural science and social science", and since these "two" cultures have different research traditions, the research of one of them is sometimes misunderstood by researchers from the other (Vallès & Goarantje 2016). Consequently, as mentioned earlier, ethnobotanical studies can be performed in many ways and from various perspectives. Some researchers work solely with historical ethnobotany and rely mainly on archives, documents, already published research, and dictionaries on for instance vernacular plant names, uses and beliefs regarding the plant world from different areas or countries. Others work with contemporary ethnobotanical information in the field, by visiting a certain community and working in contact with people in the local community, i.e. standard anthropological or ethnological methodologies.

There is a continuous discussion whether the subject of ethnobotany is more natural science than social science, the other way around or even equally of both? Belonging in two different research traditions can be seen both as a strength and a weakness. Interdisciplinary work creates opportunities to go beyond disciplinary paradigms and examine each subject in a new way. However, there is also a potential risk that interdisciplinarity might result in questioning of the validity of methodologies used by the "other" discipline and conceptual conflicts when it comes to the interpretation of data and what conclusions that could be made. In ethnobotany it is also necessary to create a functioning transdisciplinary collaboration (i.e. with people outside academia), especially in studies dealing with contemporary knowledge, which are strongly dependent on a close relationship with the knowledge holders. It has been suggested that ethnobotanical research is a form of citizen science. A close relationship between researchers and the studied community can be beneficial or problematic. On the beneficial side a close proximity may result in a sort of local "peer review" of results and conclusions, but on the other hand the scientific credibility might be questioned as the close relationship may result in an avoidance to publish "unpleasant" findings. However, available ethical guidelines are helpful for avoid potential problems (e.g. Vallés & Garnatje 2016; Tunón et al. 2016 & 2020).

Good relations are important in ethnobotanical fieldwork

As with all kinds of research, it is important to specify research questions and to consider which community to address. For example, ethnobotanical fieldwork can be linked to the ethnographic features of a certain community, to living ethno-cultural traditions, to linguistic particularities, to remoteness or isolation of a community from urban settlements or to other large communities, specific histories, particular land use and local economy or rich folklore.

To establish contacts within a community is one of the most crucial aspects of the research, and the success of the forthcoming fieldwork is dependent on this step. It is extremely helpful to have a recommendation from one of the members of the community and especially, from people that are respected. In rural communities, such as in the Romanian villages where we have done fieldwork, it may be helpful to start with contacting the mayor, the priest, veterinarians, or schoolteachers for arranging meetings with other members of the community. Another approach is to make contact with people in spontaneous meetings in the field and explain your interests and purposes.

It is also important to have an idea of how many interviews would be a minimum in order for the research to be sufficiently representative of the community. Recommendations are important, in order to come into contact with the right local experts of each subject. The methodology is referred to as the snow-ball sampling method, an anthropological qualitative research model which is successfully applied in many ethnobiological undertakings (Parker at al. 2019). For example, someone might know much about medicinal plants, another person forage mushrooms and edible plants, while others are experts on ethnoveterinary practices or ethnobiological knowledge such as fishing or livestock breeding. Traditional ecological knowledge is often not evenly spread between the members of a community, which makes it necessary to interview several people (Berkes 2008).

Botanical identification and voucher specimens

Ethnobotanical information must be linked as clearly as possible to the correct species; however, this is not always easy. It is advisable that the informants themselves have collected or physically pointed out the relevant species independently, to avoid mixing up species. If the interview is made in the absence of the species in question, it may be difficult to identify the right species because plant names used by informants may not be following the nomenclature of scholarly botany. Not even an "official" plant name in the local language or a scientific plant name may necessarily be used in a correct way. It is possible that the informant may have mistaken the botanical name and is referring to a different species. A vernacular name sometimes refers to several different species. In such cases the botanical identification will easily be erroneous. Another advantage of doing ethnobotanical interviews in the field, is that the species in the surroundings may trigger new perspectives that otherwise would have not come up.

A general rule is to always collect a voucher specimen to deposit at a university herbarium or similar for reference (Balick & Cox 1996, p. 46–51; Cunningham 2001, p. 18–19, Martin 2004, p. 28–65). Contact relevant universities prior to your study in order to include the required information with your voucher specimen. Researchers may themselves collect the species mentioned by the informants and make herbarium specimens, but then informants should also be asked to confirm that the collected species is the one referred to in the interview. The second-best option to collect voucher specimens, is to take photographs of the plants pointed out by the informants in order to secure a valid identification of the species. It is also valuable to take photographs of the surroundings where you found the plant in order to be able to interpret the ecological environment and possible human impact on the landscape (Martin 2004 p. 138–170).

Interviews and questionnaires

Interviews are probably the most important tool in ethnological, anthropological, and ethnobotanical studies. Interviews may seem easy to use, but the skill improves a lot with experience, not the least because every occasion is different. A poorly designed interview generates misinformation and makes it difficult to obtain reliable data (Albuquerque et al. 2017, p. 28).

Interviews can be performed in various ways depending on the purpose of the study. Interviews can be in the form of open-ended conversations, they can be structured very strictly, they can be semi-structured, unstructured, or something in between (Cotton 1996 p. 90–106; Martin 2004, p. 96–135; Albuquerque et al. 2017, p. 28). An open type of interview can start with a theme around which the interviewer and informant discuss, for example hay harvests. Depending on the interest and knowledge of the informant, the conversation can move freely in different directions, for example about the practical and technical aspects of hay harvests (tools, drying methods, storing, timing and time consumption), the social life of mowing (who participated, were there celebrations, music, etc.), or the subsistence aspects (the role of hay in the total economy, other kinds of feed, buying hay) etc. A structured interview uses each time the same, predetermined, questions, asked in the same order to each informant. Semi-structured interviews typically combine predetermined questions with open-ended questions in order to steer the dialogue but still being open to what comes up during the interview. Also a structured interviews can adopt open-ended questions to follow up answers, i.e. "Why?, "How?", and "What?", that can't be answered with a simple "yes" or "no".

Gary Martin stressed that "Intuition and experience are the best guides to informal ways of gathering information. When beginning fieldwork, we are drawn into a broad range of conversations. With inspiration and good luck, we find ourselves asking the questions that open the way to understanding a foreign culture" (Martin 2004, p. 109).

A questionnaire can be seen as a written list of interview-questions, that can be filled in by the informant, or by the researcher based on answers given by the informant. A limitation with questionnaires is that they are not interactive in response to the given answers. But questionnaires have the advantage of enabling the collection of information from a large number of respondents and they can easier be analyzed using quantitative methods. One result of the covid-pandemic was increased possibilities to do online-interviews, which may be a time and cost-effective alternative. The online alternative is not suitable for all occasions or all interviewees, but it may work well for example with people that are used to online meetings or when the interviewer and the interviewee already are well acquainted. Cotton also points out a need to cross-verify information retrieved from interviews and questionnaires through triangulation (1996, p. 95). When non-contradictory data are obtained with different methods or from different data sources, it strengthens the results (Albuquerque et al. 2017, p. 32–34).

Interviews can be made with several informants at the same time, for example in focus groups. Focus group interviews have successfully been applied in many ethnobiological research contexts. They are conducted with approximately four to ten people at a time. These individuals have been invited in advance to participate in the research to discuss a certain topic. The interviewer acts as a facilitator and introduces open-ended questions but mainly stays out of the conversation. The intention is that the informants engage primarily with each other, rather than with the facilitator, so that the conversation develops based on their discussion. The conversation is recorded and used in the research. One of the main deficits of this method is that it requires a long preparation time and the researchers need to take into consideration the availability of the people for the physical interviews. Furthermore, there is a risk that some informants are too dominant, and others with important perspectives may remain silent. It is important for the researcher to be observant and facilitate the interview in a way that includes all interviewees. Another deficit might be that sensitive or otherwise personal information might be less likely to be shared together with a group of people living in the same location. In order to overcome the two last weaknesses, follow up interviews can be made in smaller groups. One of the main benefits of this method is that the interviewees can validate and reflect upon the answers given by other participants and thus creating a constructive dialogue that may come up with more in-depth information.

Figure 7.5. During field work about Romanians alder meadows, interviews were taking place partly through participation in the work. Being in the field together with the informants during harvest, facilitates and deepens the discussion on various aspects on and relating to hay. Botiza, Romania. Photo: Anna Westin.

The artefact interview method was developed by Brian M. Boom in the 1980's and is a methodology where the interview departs from an artefact made from plants or a particular plant use context (Balick & Cox 1996, p. 44). This method creates opportunities to highlight aspects of a particular subject that would not come to the mind of the interviewee in a 'formal' interview (unless the interviewer already had very good knowledge of the subject). Artefact interviews using photographs or other depictions of plant species or specific activities may be particularly suitable during ex situ situations. The pictures should preferably show fresh plant material in situ. It is also valuable if the pictures show as much detail as possible of, for instance, the flowers, fruits, bark, stem cuttings, exudates, and associated fauna and/or flora. Such depictions can be useful even at occasions outside the vegetation period. Some studies have shown that the informants have better possibilities to recognize species from a photograph compared to a voucher specimen (Thomas et al. 2007). Such interviews can also be made in situ in a place relevant for the subject of the interview, a method sometimes called place-based elicitation (Figure 7.5.). Being in a landscape where the plants in the centre of the interview are present, can evoke knowledge and memories that the informant otherwise would not have mentioned.

A methodology used in Sweden by the siblings Yngve and Lilian Ryd is deep interviews with a very limited number of informants. They have focused on describing practices and practical traditions among elderly Saami people around Jokkmokk in the North of Sweden; a work that has resulted in many books. The methodology is simple: to repeatedly and for several hours at the time interview and discuss a particular subject with the informant. The interview sessions are often repeated several days in a row to dwell deeper and deeper into details and to find inconsistencies in the answers. After each interview session the researcher analyzes and rewrites the notes into a logical story and identifies new questions for the next sessions the following day. It is important to have repeated sessions over a short timespan since the technique brings back or reconstructs memories that have been "forgotten" and memories that the informant was unaware of having (Ryd 2009, 2010a; Ryd 2010b).

A quick guide to vast knowledge systems, according to Yngve Ryd (2009):

- Discuss the same question with the same informant several times in order to get the details right.
- Be persistent. If an unanswered question is repeated several times an answer may come.
- Revisit good informants over and over again. If they remember one subject well, they can probably deliver information on other subjects.
- Knowledge is best retrieved at the "kitchen table" where it is necessary to find verbal explanations. When in the field it is far too easy to just point as an explanation.
- Total focus during the interview session, and the time for a break. It is not a leisurely conversation.
- Be aware that physical frailty does not necessarily reflect the mental state of the informant. They can still have a good memory.
- There are more relevant subjects than researchers so encourage people to write down their knowledge if possible.
- Many different subjects are described in the literature, a white spot (hole) in the knowledge system is only identified through the interaction with informants.
- It is not serious to have a time plan. A time plan may have a limiting effect and contribute to a premature termination of a project.

Participatory methods

In interviews, the informant often takes a relatively passive role, as opposed to participatory methods where the informants are highly active. The idea is that the participation should be non-hierarchical and egalitarian to give all participants a voice (Martin 2004, p. 5–10, 107–109; Cunningham, 2001 p. 23–26). In Participatory Rural Appraisal (PRA), local people take active part throughout the study "in the design of the study, data collection, analysis of the findings and discussions of how the results can be applied for the benefit of the community."

Transect walks are a participatory methodology where the researchers and members from the community follow a defined path and data is collected during the walk. The transect walks can focus on all sort of cultural activities or other subjects, e.g. use of medicinal plants, edible plants, or natural resource in general, as well as geographical organization of village life. It can also be used to establish a better contact between the researcher and the community due to the relatively relaxed and casual conditions of such a study. The method can be used with ordinary people or key informants and is focused on creating an opportunity to discuss, observe, identify and reflect over relevant items for the village (Cunningham 2001, p. 23).

Timelines are a method that can be used to identify historic events, game-changers, turning points, or anything of importance for an area or connected to a particular land use. Events on a timeline could be the year for the introduction of a specific technology, the implementation of a new regulation related to land use, forest fires or an important climate incident. Timelines gives a possibility to evaluate how past events made a difference for people, their use of resources, or how important land uses have changed (Cunningham 2001, p. 23).

Creating seasonal calendars is a method to visualise the annuality of important land uses and biological resources (Cunningham 2001, p. 23). What do people do in different seasons? What are the important activities over the year? What resources are harvested during what months?

Ecomapping, land use mapping, cultural mapping, or village mapping depending on the scale, are different names describing a participatory method where members of the community put "cultural data" on a map. It is often used to visualise the local community's connection to their traditional territories, but is also useful to indicate other aspects of people's relationships with the landscape. Ethnobotanical mapping can include the occurrences of different kinds of plants that are used by the community. An important ambassador for this method is the British anthropologist Hugh Brody, who has used ecomapping in many different projects to empower local communities in different parts of the world. His book Maps and dreams (Brody 1981) is something of a classic in explaining the underlying ideas of this methodology. Another practical manual is Chief Kerry's moose – a guidebook to land use and occupancy mapping, research design and data collection (Tobias 2000). It is rich in hands-on experiences and inspiration for how to design such a study. Mapping can be done directly on a map or on a clean paper depending on availability. We suggest starting a mapping session by asking the participant to describe the geographical characteristics of their landscapes in order to create the framework of the map. What are the characteristic features of the landscape? Hills, waterways, lakes, mires, etc. Then continue with drawing the different kinds of land uses performed at specific places, and how people move in the landscape. What are places that are of particular importance to the local community or fractions of it? What do they do there? When? How? and Why? This information may then be corroborated during field visits to the different areas by finding elements in the landscape that support their stories (Tunón & Byström 2010, p. 285–296).

Citizen science projects use observations and data contributed by members of local communities and other "citizens". The projects are planned and designed by researchers, who also analyze the data and interpret findings. In citizen sience, the role of the "citizens" is only to contribute with information to a specific research context (e.g. Fraisl et al. 2022). This is in contrast to community-based monitoring (CBM), where the local community documents data based on their own interests (Reyes-García et al. 2022). People in the local community identify a need and design a project to meet it, sometimes in collaboration with researcher, but not always; the initiative originates always from the community.

Photovoice is another methodology with potentials for ethnobotany and historical ecology (Sutton-Brown 2014; Dedrick 2018, Carroll et al. 2018). The method was developed in the 1990's and has, according to our knowledge, not come to any common use within Historical Ecology. It is often used by marginalized groups to visually identify, document, and represent cultural aspects within their community. The members take or select photographs depicting what they consider typical, characteristic, or relevant for specific concepts or contexts. What is, for instance, an adequate representation of medicinal plant use in your community? Or, can the different stages in hay harvests in your village be depicted?

Local markets are an interesting source of data, highlighted by Anthony B. Cunningham and Gary Martin (Cunningham 2001, p. 60–95; Martin 2004, p. 191–200). Both authors deliver valuable insights in how markets work and their values to the local economy and that they may play an important role as part of a trade network. Martin points out that any study of the economic values of biodiversity must take the local markets into account as many plant species that have a strict local value meaning only will appear on local marketplaces. Therefore, they claim, surveys of biological resources must include talking to producers, sellers, and consumers. When doing such surveys, Martin lists the following important aspects: information on the vendor; origin of the produce; condition of the goods; management and marketing of the resource; quantity, price and availability; changes in demand and supply; and additional information.

Participatory methodologies can be seen as versions of dialogue workshops or focus group interviews in the field. Balick and Cox (1996) argue that formal interviews, where interviewers have a more objective role to the community, are difficult to combine with participatory methods. Also since the latter aims to "consciously reduce the formal distance between observer and subject, they are vulnerable to the criticism that they move too deeply into indigenous paradigms" (p. 43). The ethical issues of close proximity in Community Based Participatory Research (CBPR) projects have previously been highlighted by Tunón et al. (2020). When it comes to participatory methodologies, Participatory Learning & Action: A trainer's guide (Pretty et al. 1995) can be recommended for inspiration.

Ethical implications and access and benefit sharing

Researchers and adventurers have studied the practices and the knowledge of indigenous and local communities for centuries. For a very long time there was very little respect towards the knowledge holders. However, things slowly started to change, and in 1988 the International Society of Ethnobiology (ISE) held a congress in Belém and decided on the Declaration of Belém, a document highlighting the responsibilities researchers have towards the local people that supply their knowledge to scientific studies. This has since been developed into an ISE Ethics Programme and the ICE Code of Ethics with 17 principles and 12 practical guidelines. Compulsory elements are the issue of free, prior informed consent and the principles of precaution and diligence, as well as the issue of reciprocity and giving back to the community. The latter, to present the findings for the local community and not only for the scientific community, is an often neglected element in research projects. The ICE Code of Ethics is one of many valuable guidelines to ensure the rights of the local people. It is important to stress that ethical behavior is not just about ticking off the right boxes in a list of principles, but rather a respectful relationship between researchers and a local community. This process is often time consuming, and researchers need to invest enough time to meet and get acquainted with the community and finally be accepted by it. To be familiar with the challenges, responsibilities, and provocations of folk biological research, it is necessary to consult the emerging literature on this subject and also to adhere to appropriate ethical guidelines. Practicing full disclosure is beneficial for both the researcher and the local community, since much of this type of research is in fact co-production of knowledge (Berkes 2008) and might also help the local community in several ways in the long run. A problem is that, for the researcher, this relationship is often limited to a specific, often relatively short period relating to a funded project, while the local community is looking for a long term and more reliable liaison (Tunón et al. 2016).

Another important issue is intellectual property rights and access and benefit sharing (ABS). The first principle of the ISE Code of Ethics states that:

> "Indigenous peoples, traditional societies, and local communities have prior, proprietary rights over, interests in and cultural responsibilities for all air, land, and waterways, and the natural

> resources within them that these peoples have traditionally inhabited or used, together with all knowledge, intellectual property and traditional resource rights associated with such resources and their use."

Consequently, the informants own their knowledge, and this ownership must be respected in ethical fieldwork. Often people are happy to share their knowledge with people they trust, and it may be tempting to collect information for future publications without disclosing to the local people what it will be used for. That people share information with you does not necessarily mean that they give you the permission to spread it further. To collect data for future studies without informed consent was common in the past, but it is now considered unethical. Therefore, all field work nowadays requires that researchers first inform the participants and get consent prior to the study. In practice, this means that the researcher must give full information about their interests and the purpose of the research (nature conservation, epistemological value, cultural heritage, development of new drugs or other reasons) as well as the planned outcomes (types of publications, exhibitions etc.) before informants agree to take part in the study. The researcher should also give the informants their contact information, if the informants change their mind or if they want to add information afterwards. From serious journals, prior informed consent may be a requirement for being able publishing the results. It is always advisable to let the interviewees read the minutes from the interviews and suggest corrections. Sometimes, key informants might even be integrated in the research team and become co-authors (see also chapter 10). Also, in order to collect specimens from different plant species, it might be advisable to have permission of the community or at least of the landowner, if the species is found on private land. In this case it is always important to consider the national conditions since national regulation may differ.

Apart from the ethical permissions from the local community, it may be necessary to have permissions from the government. The negotiations of the UN Convention on Biological Diversity (CBD) have resulted in the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization, a global framework for ABS-issues, which also regulate the access to "traditional knowledge associated with genetic resources" when it comes to bilateral exchange. It is important to keep track of what requirements for due diligence are applicable for the countries of the research group as well as the knowledge holders. Researchers in the European Union need to pay due respect to the EU regulation (511/2014) on compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union.

Ethnobotanical studies in archives and literature

Plants in historical documents

Plants of economic interest are mentioned in various historical documents, and some of this information may be of ethnobotanical relevance. Cadastral maps from Sweden, which recorded economic (taxation) capacity of farms and villages, may contain information about the abundance of woody species used for firewood, timber, fencing and roofing (reed, birch bark) etc. (see also chapter 2). Any disputed resource is also likely to occur in court records. Unless the purpose of the source was to document plants and their uses, the ethnobotanical information in these sources can be expected to be biased towards economically interesting species and occasional anecdotal records.

Ethnographic sources

In the urge to document folklore and traditional lifestyles, ethnological institutions in different European countries have long collected information from rural people (Tunón 2015, with the distribution of questionnaires about traditional customs, agriculture, language, beliefs, infrastructure, childcare and many other themes (see also chapter 2). For example, in Sweden, hundreds of different questionnaires have been distributed to informants around the country since the early 20th century. Many of the questionnaires include questions relating to plants, and specific ethnobotanical questionnaires have also been sent out. The replies to these questionnaires are rich sources to the diverse relationships between people and plants in the past. However, one should be aware of source critical aspects. At least during the early days, informants were rather restricted in their answers by the formulations of questions and the communication with the museum officials (Wall & Richette 2010; Östling 2010).

Literature

Literature of ethnobotanical relevance can be found from Antiquity and onwards. However, sources must be treated on a case-by-case basis. Some literature is based on firsthand experience while others are at best secondary or tertiary sources. Many books are compilations of information of unknown origin and/or bad translations from other languages. Another common problem with elderly literature is that authors sometimes tend to "translate" foreign plant species into "comparable" native species, more understandable to the local readers, which may lead to a situation where a particular plant is erroneously claimed to have been used in a certain situation. Descriptions of a particular use may also be appearing in several different sources without enough information to make it possible to determine that it is actually describing the same, or different, cases. One important category of literature are travelogues by travelers such as Carl Linnaeus and his disciples, where findings were made public for a larger audience. These books are often botanically correct and the knowledge and uses are often localized to an exact place and a defined date. However, they do have a tendency to leave out observations of common species and activities and focus on the more things they found "interesting" and that made impression on them. Consequently, as a common rule, an absence in a source does not necessarily mean an absence in reality. Another inspiring source is descriptions in fictional literature, like novels, short stories, and poetry, even if they are not always ethnologically entirely correct, they may deliver local perspectives on plants and plant uses.

From the 20th century onward, there is also a rich body of literature where ethnobotanical knowledge-based information from various sources (including older literature and field work), have been synthesised into valuable publications. For instance, from the Nordic countries there is the Danish Folk og flora [People and flora] by Vagn J. Brøndegaard (1978–1980), Norwegian Planter og tradisjon [Plants and tradition] by Ove Arbo Høeg (1976), and Swedish Människan och floran [Man and flora] (edited by Tunón et al., 2005). The perspective of these books differ slightly. While Brøndegaard's volumes mainly are based on literature sources, Høeg's book is based on the stories of a huge number of local informants. Tunón et al. have edited a multi-disciplinary anthology with a large number of scholars, thus being a scientific–popular scientific meta-study of historical and contemporary plant use in Sweden. Comparable books have been produced in several different countries and give a good background for further studies no matter if it refers to local conditions or at a higher level.

Examples of ethnobotanical research projects and methods

Ethnobotany can be integrated into several research projects and undertakings in Historical Ecology, nature conservation, and also in immaterial and material cultural heritage and traditions. Here we will exemplify ethnobotanical methods through case studies and methodological considerations from our own and other people's work.

Integrating ethnobotany into ethnographic research in Romania

In the project FOODIE, a team of anthropologists and ethnologists researched the diverse and uncharted domain of traditional foods in Romania and historic Romanian speaking communities outside the national borders. Ethnobotany was integrated as an important dimension of research. In the local cuisine of rural communities there are a considerable number of wild plant species used for preparing different dishes (Figure 7.6). Several wild plants are also used for medicinal beverages or recreational teas (Sõukand et al. 2013). The project also recorded traditional and local varieties of fruit trees that were planted in gardens and orchards. FOODIE is an example of how ethnobotany is starting to be acknowledged and integrated as an important method of research, diversifying the research base of food studies (see also Pieroni and Leimer Price 2006, Fontefrancesco et al. 2022, Sõukand et al. 2013).

Figure 7.6. Left: A traditional fermented cider-like drink called oțet or acritură in the Apuseni Mountains, made from lingonberry (*Vaccinium vitis-idaea*). Photo Cosmin **Ivașcu**. Right: Mushrooms are collected in many rural areas of Romania, both by rural and urban people. Many rural people have traditional knowledge regarding many edible mushroom species, and through a wide variety of books, mushrooms have been made more available to forage for everyone. This picture shows a traditional mushroom stew made predominantly from the chanterelle (*Cantharellus cibarius*) served with polenta. Photo Cosmin **Ivașcu**.

Impact by external sources of plant knowledge in southeast Europe

Impressive traditional plant knowledge is still alive in rural communities of Romania. In one community in Maramureș, most of the locals recommended a person whom they considered the expert in the use of medicinal plants from the local flora. He had extremely detailed knowledge about medicinal use. However, a first noticeable impression was that he did not use local plant names, but more common, standard names, found in books on biology and medicinal plants. He showed us that his main source of knowledge was the book Health from God's Garden: Herbal Remedies for Glowing Health and Well-Being, written by the Austrian author Maria Treben (1987, first published in German in 1980). The book has become a best seller of traditional Austrian and Central European medicinal plant use, common especially in Central European countries, but after the 1990 is also beginning to be quite common in Eastern European countries. Although the local expert was familiar with the local methods and practices on plants, he considered them to be less trustworthy than the practices described in the book.

A similar event took place during field work in Banat, southwest Romania, where another local plant expert, familiar with many traditional practices, used the book by Maria Treben as the primary source of reliable information. The Hungarian edition of Treben's book is quite widespread among the Csángós, eastern Carpatians, affecting the vernacular plant nomenclature in this area and the medicinal use of plants (Babai & Molnar 2016). Mattalia et al. (2020) found that the Hutsuls living in Ukraine, were very fond of their books regarding the topic of medicinal use of plants and herbal tea recipes, among them Maria Treben's book. Furthermore, Ukrainian Hutsul used books and newspapers more commonly than Hutsul living in Romania. This phenomenon was linked to the emergence and spread of popular books on medicinal plants within the USSR starting with the year 1970 that had success, being re-issued several times (Mattalia et al. 2020).

During our fieldwork with the FOODie project research team (see above), in the Republic of Moldova, which was part of USSR from 1945 until 1991, we observed that some locals specialized in medicinal plants collection and cultivation. Also here, we found a strong component of knowledge acquired from reading popular medicinal books in the former USSR and from magazines. The plants were collected from the own garden and other areas from the village and then sold at a local level mainly dried to be used as tea for medicinal purposes or recreation. The external influence was obvious especially regarding local species nomenclature (using some Russian plant names). This does not mean traditional ethnobiological knowledge is not present anymore, on the contrary, it might be present but also adapted to new socio-economic conditions of the local communities.

By studying historical ethnobotanical literature from the interwar period, it is clear that many communities from the Republic of Moldova (at that time called Bessarabia and was a part of the Romanian Kingdom) had incredibly rich ethnobotanical knowledge and very elaborate receipes for the preparation of medicinal teas to treat different illnesses. When such cases are encountered, it is mandatory that the researcher try to identify the influence of external sources in local intergenerationally transmitted knowledge, especially when the rest of the community considers certain persons as local experts (see Bexultanova et al. 2022, Mattalia et al. 2020). The existence of local experts specialized in medicinal plants with external knowledge sources (books, magazines) is a recent reality in (south-eastern) European rural communities, but researchers should not underestimate the traditions of peasant herbalists that might still exist in some European regions.

Ethnobotany as an important source of information in nature conservation

There are good reasons to do ethnobotanical research within landscapes with remarkable plant diversity such as high nature value (HNV) farming, diverse cultural landscapes. and species rich grasslands. Learning from the local communities, how they classify and use the different plant taxa and how they classify and manage different vegetation types, will inform nature conservation about possible ways of land management.

In the Romanian Eastern Carpathians, a Hungarian ethnic group (Csángó) practices small-scale agriculture in one of Europe's youngest cultural landscapes with species rich grasslands. The Csángós have deep ecological knowledge on the vegetation structure, a complex folk habitat classification, but also a rich local nomenclature and medicinal knowledge on many of the species that grow on the semi-natural grasslands in their landscape (Babai & Molnar 2016). Other communities with a long history of complex intertwined practices of cereal cultivation and pastoralism in the mountainous region of Maramureş have developed an extremely interesting and detailed classification of hay according to several ecological factors (altitude, slope orientation, dominant plant species etc.) being around 16 categories in one village (Ivașcu et al. 2016). The classification of hay was common also in other villages from in Maramureş and coincided with a deep knowledge among the locals for other medicinal, tinctorial, food and other uses of the wild plants growing in the landscape. In some other areas we found a less complex classification of hay, either due to environmental or cultural factors (e.g. Banat, Bucovina etc.) (Ivașcu unpublished). This shows that local communities practicing traditional methods of agriculture and animal husbandry still possess incredibly detailed knowledge of vegetation and habitat dynamics as well as the management shaping them. Learning from these people will enable more successful management in areas where traditions have been lost but biodiversity is still rich.

Experiences from ecomapping in the North

During the last decades we have used ecomapping to visualise land use in several studies, for example with summer farmers in Western Dalecarlia, in the central parts of Sweden. Summer farming is a form of sedentary transhumance pastoralism where one or more satellite farms are situated further away in the outlying lands, in order to utilize grazing resources too far to reach on a daily basis from the central farm. Historically the animals were herded to graze in the forests, mires, or alpine meadows in the vicinity of the summer farm. Today the animals are most often free ranging or fenced in the infields (Tunón & Bele 2019). In our study we mapped the areas grazed by the livestock, according to the summer farmers, along with other local information about e.g. nature values, important areas, and stories about the animal husbandry (Figure 7.7.). Among other things, the study showed that the infields, as defined by the National Board of Agriculture, constituted of on average 7.3 % of the total grazing area that the farmers pointed out as grazed by their livestock (Poudel 2010).

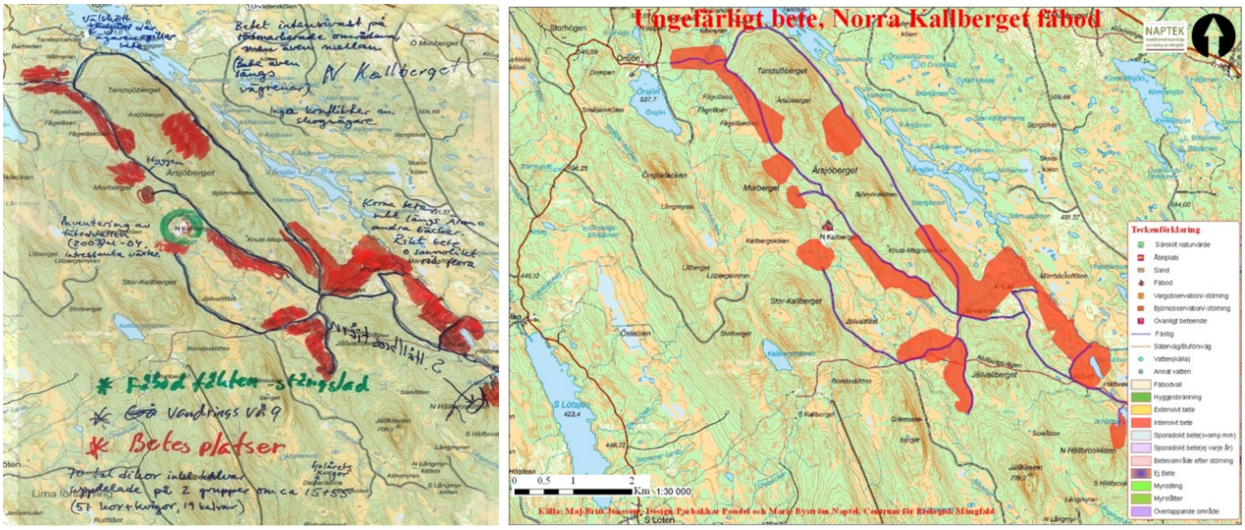


Figure 7.7. The sketch made by the farmer (left) is translated into a GIS-map (right), which gives us the opportunity to calculate grazed areas and also to show the areas used by this particular summer farm in relation to other summer farms in the vicinity.

In an assignment from the Government of Åland in 2019, we used participatory ecomapping techniques to document the multiple use of coastal areas on Åland, for the development of a coastal and marine spatial planning document. In several focus group interviews and dialogue workshops, fishers, hunters, local heritage people and others from the local community discussed different aspects and uses of the coastal area with the purpose to identify valuable areas for different parts of the communities and reduce the risks of future conflicts. One of the results from this study was a map over the perceptions of status and trends of coastal birds in different parts of the Åland archipelago (Figure 7.8; Tunón et al. 2020).

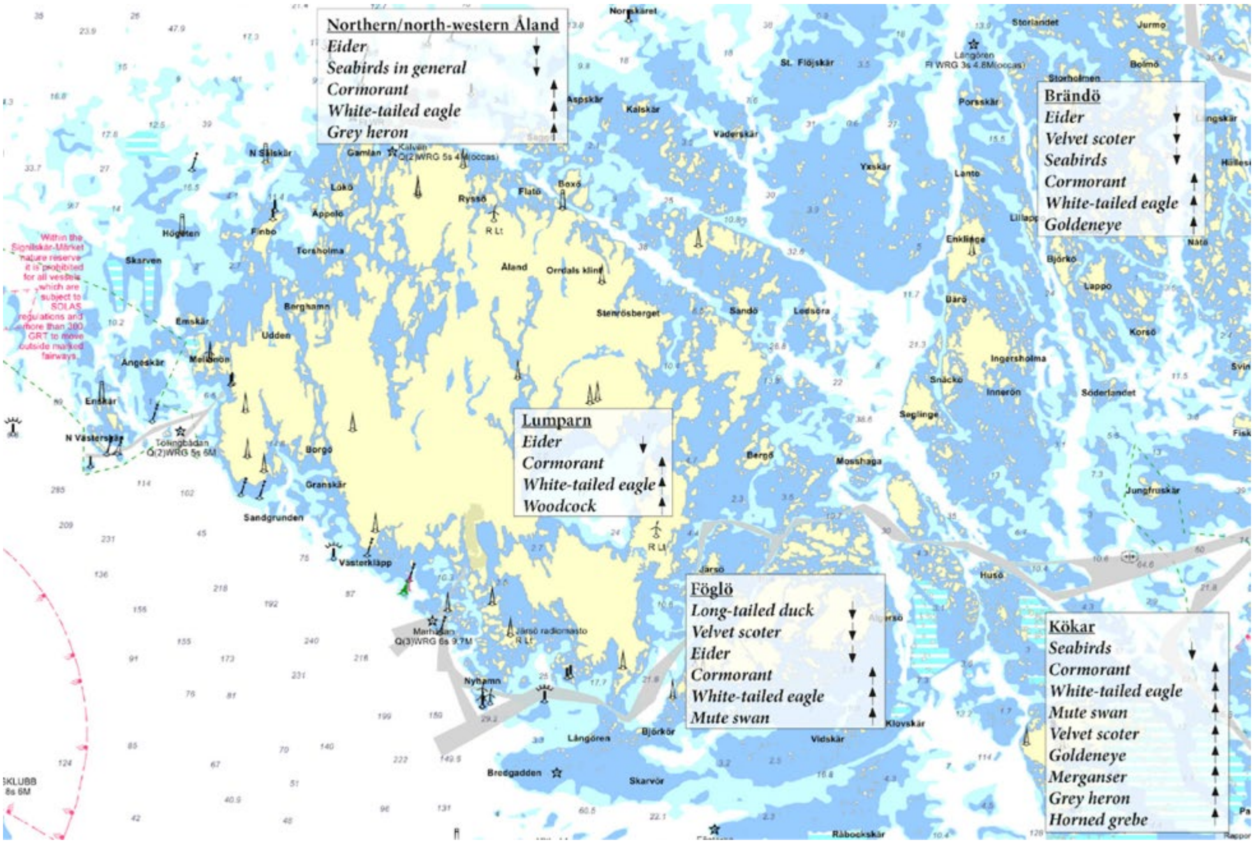


Figure 7.8. A map over the trends of coastal birds in the Åland archipelago based on combined statements by local people in a number of focus group interviews and dialogue workshops. Upward pointing arrow means that the population of the bird species is increasing, and vice versa.

In another project, we helped the local communities in the archipelago south of Kalix in Northern Sweden to visualize their experiences from net fishing in the shallow coastal waters. In this case they documented all their catches during one year, marked the different species on a map, and then calculated the risks of getting by-catches of the endangered brown trout. This project produced a map to show the authorities where fishing could be continued and where it is advisable not to fish for conservation purposes (Kvarnström & Boström 2018). This example was about fishing, but it could be developed for most subjects, e.g. harvest of berries, mushrooms, or medicinal plants.

Such participatory activities have also resulted in the inclusion of local people as co-authors, e.g. key informants. We will highlight one case in which prior studies and discussions have led to joint ideas to highlight particular issues of importance for the local communities and consequently co-authorship with locals (Tunón et al. 2019). The writing process departed from a joint idea that was sketched out by the researchers, and then developed by the local representatives. Joint discussion led to a draft structure that was adapted with input from all. Experience-based comments from the local perspective were braided with reflections from the scientific literature. Data were evaluated and scrutinized jointly to produce a picture that was equally correct from both sides. Interestingly enough, the referees on the paper saw a problem in the fact that we didn't have any literature references to rely on when it came to the local representatives' experience-based data. This highlights the need in co-authored publications, to develop acceptance that both researchers and local experts have equally valid knowledge and perspectives. Both contribute with important pieces to the puzzle for the completion of the picture. The importance of being humble and responsive is valid for both sides.

Ethnobotanical research in literature and archives

In the Northern parts of Scandinavia reside the Saami people, Europe's only indigenous people. Scholars have repeatedly studied and documented their customs and practices through the centuries with different purposes and methods. In one study, a compilation of the documentation of Saami use of medical cures was needed (Tunón 2000). When comparing information in older literature you may get the impression that some cures were more common than they probably were, since the authors have "borrowed" information from each other, rewritten and without citations. Repeated reports in the literature, when investigated further, might in fact have originated from one particular case. We have also experienced that scholars documenting local traditions often seems to have a bias towards describing the more uncommon, "exotic" practices. For instance, when looking at the archives with ethnological records of folk medicine in Southern Lappland, you easily get the impression that one of the most common medicinal plants was mezereon or february daphne (*Daphne mezereum*), a very poisonous plant. In the ethnological material, it is one of the most abundant medicinal plants where it is described for a variety of uses. We find it most likely that treatments with less conspicuous plants have made less impression on the informants and consequently that they are underrepresented in the material. It may be that the informants have focused on more severe illnesses and, hence, many informants mention mezereon.

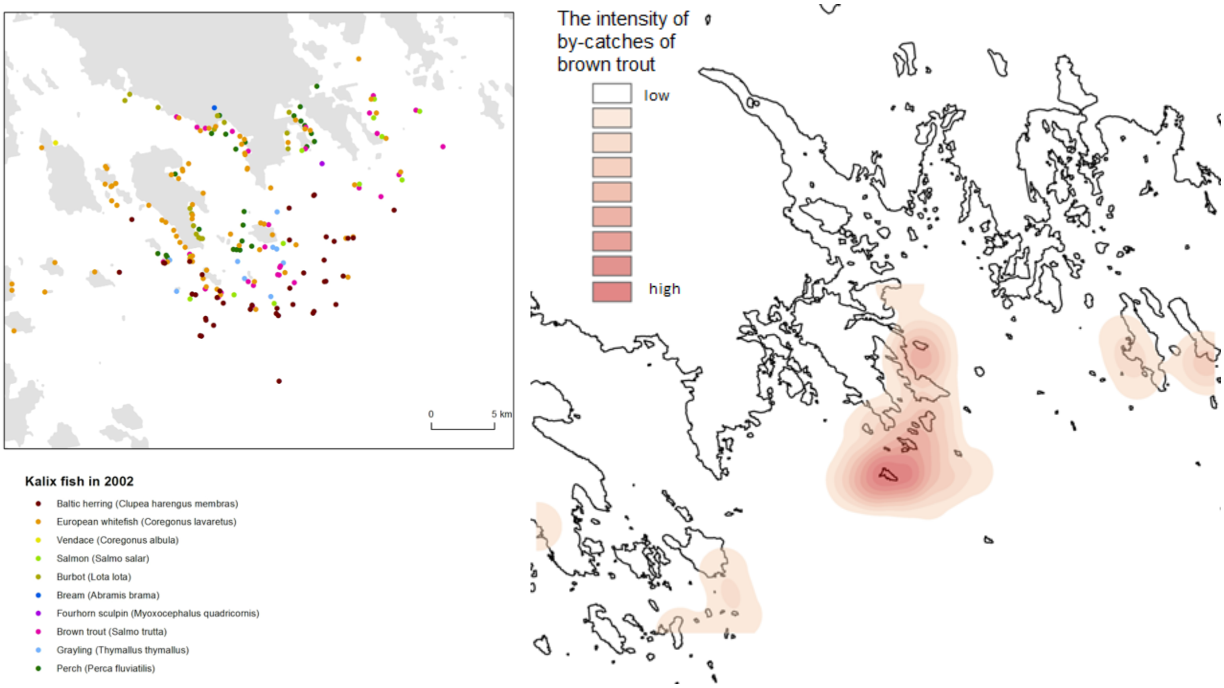


Figure 7.9. Two maps from the archipelago south of Kalix, (left) a map with colored dots depending on the different fish species caught while fishing, and (right) an intensity map over the likelihood to catch the endangered brown trout.

Local reflections on photographs

We have also used historical photographs as a focus of discussion with local people, as a way to acquire knowledge deriving from local traditions that otherwise would not have been known to us (Figure 7.10). This can be done from only a few photographs or by applying systematic methods using several photographs, showing similar or different motives. People with local knowledge can usually add something to each photograph, but it is difficult to predict how much information they have.

Figure 7.10. Left: Hay harvest in Funäsdalen, mountainous parts of west-central Sweden, 1928. Due to geographical and climatological conditions here, most of the fields were used for hay. Normally the farmer continued the harvest from one field to another and brought home the hay when it was dry enough. In this picture we can see that most meadows are still filled with hay racks, which tells us that the hay was still not dry enough to be stored. An interpretation is that this must have been a wet summer. Right: A farm at Visingsö, Sweden, in late summer, 1933. The harvested cereals were stored in different stacks. Later in the autumn, after the threshing, the straw was kept in new stacks in case the fodder the following year would be scarce.

Plant names, historical habitats and plant use

Plant names can be a gateway into past landscapes, plant use and traditional systems. Names can be descriptive to the plant's characteristics such as taste (acris – bitter), color (album – white), or size (major – large). Many names inform about the main growth places such as "sylvaticum", meaning forest, "pratensis" or "pratense" meaning open land (meadow), and "montanum" for growing in mountains. Species names can also inform about historical plant uses. For example, "tinctoria" signifies plants used to dye textiles, and "officinale", shows that the plants have been used for medicinal purposes (Figure 7.11). This information may also be given in the common names, such as Swedish plant names containing colour "färg-"; färgkulla – *Anthemis tinctoria*, and färgmåra – *Asperula tinctoria*.

Plant names may lead to insight into past times religious beliefs and practices. In Sweden, and internationally, Virgin Mary has been important for the local naming of plants. In German speaking countries there are over 180 different plant species named after her, in Sweden around 60 species are known to have carried names related to Virgin Mary. Plant names including Virgin Mary remind us about folk religion in past times and how important she was for people in their daily lives. It was common to include Mary in prayers and ask for her help, not the least during childbirth (Herjulfsdotter 2013).

Common plant names have often been chosen from the richness of traditional local names and may be very informative. In Sweden, where the traditional landscape has lost most of its traditional land use and habitats, many plants have been forced to survive in other, perhaps less optimal habitats. The names may still inform us about where they used to be common (Figure 7.12). There are a great number of plant names including äng- or slåtter- (hay meadow or mowing), such as ängsskallra – *Rhinanthus minor,* ängskovall – *Melampyrum pratense*, slåttergubbe – *Arnica montana,* and slåtterfibbla - *Hypochaeris maculata*. It may indicate that hay meadows used to be the main habitat for these species. Another interesting group of species include åker- (arable), which may be a clue that these used to be weeds in arable fields.

Figure 7.11. The plant *Peucedanum ostruthium* has been considered a powerful plant, revealed by its common names in several European languages referring to "master" (English masterwort, Swedish mästerrot). Today, a more or less forgotten plant but historically a commonly cultivated plant which may survive and spread in light conditions to cover large surfaces around old farms and summer farms (as a biological cultural heritage). It has been used in various cures for humans and livestock (hence the Swedish local name "kobot" [cows cure]. Modern research has revealed that the constituents in its root indeed have inhibiting effects on infections, fever and mycobacterial growth. Photo: Anna Westin.

Contributions to Historical Ecology

The wild plant use in the last centuries or even decades might have been more detailed, complex and more general compared to the current use in many of the world's indigenous and especially rural European communities. During the last decades, the erosion of traditional knowledge has accelerated, and especially in our modern technological society where people have lost contact with nature. In many countries, traditional ethnobotanical knowledge is forgotten among most people. It may therefore be difficult for us today to understand the great historical importance of plants for people. Ethnobotanical research, in the past and present, has the capacity to help us better understand historical people and communities through their relations to plants.

Ethnobotanical information can give us details on how different plants were used, including plant taxa that were not subject to documentation in most other sources. An important characteristic of ethnobotany is that it focuses on how ordinary people, including locally consulted experts, have actually used, and related to plants in their everyday lives. This information comes directly from the people using plants themselves, or via another person who met the plant users, through interviews and written documentation. The richness of interactions between humans and the plant world offers insights into the great importance of plants for people. Through research about plant practices and beliefs, ethnobotany gives more life to Historical Ecology than many other sources of knowledge. Having at least some information on the extent and numbers of species of wild plants that a community used in the past, for medicine, food, to organize herding and agricultural practices, construction etc. is highly important, in order to understand the connection and influence ecosystems have played on humans through the centuries.

Figure 7.12. *Rhinanthus angustifolius*, greater yellow rattle, in Swedish called höskallra (hay rattle) which indicates its close connection to hay meadows. The name rattle (also in the Romanian common name clocotici) comes from the rattling sound of the mature seeds, which has been a common indication for the right time to start mowing. This species is one of many phenological indicators for mowing time. Photo: Anna Westin.

Plants have been the most important basis for material culture and used in building constructions, tools, clothes and much more. For example, reed (*Phragmites australis*) has been important for the construction of household parts and covering the roofs of many houses in European countries which had wetlands areas. In Sweden, the bark of birch (*Betula* spp.) was also used both for roofing and making baskets, shoes, bowls and other household containers. Willow (*Salix* spp.) was used for basketry production and fences. In the past, whole communities specialized in making baskets and other kinds of crafts.

Foraging edible wild plants played an important role in the not-so-distant past for supplementing domestic food resources. In Romania, wild fruit trees such as wild apple trees (*Malus sylvaticus*) and wild pear trees (*Pyrus pyraster*) were important in the past for producing cider-like drinks, or dried and used for human consumption. Other plants that were introduced from the New World like the Jerusalem artichoke (*Helianthus tuberosus*) were semi-cultivated (planted in certain spots and only harvested in autumn) and used for preparing dishes. The slightly toxic plant meadow buttercup (*Ranunculus acris*) was used in some areas of Romania as fresh green soup in spring, the toxins being neutralized during cooking. The list of edible and medicinal wild plants can be extensive. These plants had a significant but varying degree of importance in different communities (see bibliographic resources cited in this chapter).

Another interesting type of knowledge is the linkages between the phenophase of certain plant species and the start of specific agricultural or pastoral practices. This topic shows the importance of wild plants as natural indicators for human activities. In many regions of Romania, the flowering of blackthorn (*Prunus spinosa*) most commonly called spin or porumb (meaning corn), signaled that the cultivation of corn (*Zea mays*) can start. When the hay rattle (*Rhinathus minor, Rhinanthus spp.),* has mature seeds that sound like a rattle, has been an indicator for the start of mowing season in Romania (Figure 7.12.). This indicator is still used in many rural communities from Romania (Ivaşcu et al. 2016, Iuga 2016). The sounds of hay rattle have indicated the start of mowing also in other countries like Sweden (Tunón et al. 2015) and England (Burton & Riley 2018). There are many other practices relating to plant phenotypes, showing examples of the seasonality of traditional human economic activities known from history and current rural communities.

Plants have also had an important role for decoration in houses and in customs (Figure 7.13). Magic and divination were important in people's everyday lives, and plants have been important in foretelling or affecting the future. Ethnobotanical knowledge still known in Sweden today is the practice of getting information about a future husband by placing seven or nine kinds of flowers under the pillow during Midsummer night. The girl had to follow certain procedures in order for the divination to work, for example picking the flowers in silence, climbing seven fences, and speaking to no one during the entire evening.

Figure 7.13. Left: Wreath of flowers, predominantly made of yellow bedstraw (*Galium verum*) called sânziana in Romanian, affixed to a gate for protection in Banat on the eve of Saint John's Day (24 June). The yellow bedstraw is usually collected on the 23 June, mostly by women and children who also make the wreaths. The wreaths and braidings are used in different apotropaic and divinatory practices around Romania on the Day of Saint John. Photo Cosmin Ivaşcu. Right: A silver fir tree (*Abies alba*) adorned with flowers and round bread is an important symbol of the milk measurement custom in Maramureş. This custom marks the advent of summer grazing and the movement of sheep herds to the summer pastures. The fir tree symbolizes the tree of life in Romanian culture. Photo Cosmin Ivaşcu.

Do’s and don’ts, benefits and shortcomings in ethnobotany

Ethnobotanical studies can provide unique insights into how people relate to plants, whether it's about practical usage or beliefs. The interdisciplinary approach provides knowledge about both the plants, the people, and their lives, both today and in the past. However, like for all subjects, there are limitations. The strengths and weaknesses of the different methods have been described above. Similarly, it is important to recognize that knowledge, both found in books and in people's own understanding, is a mixture of local and imported, historical and newly acquired knowledge. It is important to be aware that different people possess different depths of knowledge. People who have practical experience, for example, in making baskets from spruce roots, have a completely different understanding of the craft than those who have only observed the process or maybe only have used the baskets. There may also be informants who pass on stories about the craft, but without having either made or used the baskets themselves. Therefore, it is crucial to be informed about the informants’ level of knowledge in order to assess their answers. When it comes to practical, experience-based knowledge, it is also important to acknowledge that different people experience and remember situations differently and will describe them differently. Also, we need to acknowledge that remembering is a process, not an objective recall of events that is stored in the brain. In fact, memory research shows that memory is not something we have, rather something we do (Hilding-Rydevik et al. 2018).

> “The indigenous people, or the farmer, knowing their environment, appear to employ traditional techniques that harmonize the need for management and conservation of resources. However, this is not always true. It is a mistake to sustain the belief that all the so-called traditional cultures have harmonious relationships with nature, because there are studies that definitely suggest the opposite,” (Albuquerque et al. 2016 p. 20)

It is easy to fall into the belief that the locals always have a good and environmentally friendly relationship with all other species in nature, when in fact traditional communities have also contributed with negative impacts such as over-harvesting, local soil depletion or pollution. We suggest having an open mind and a non-value-approach to all kinds of information that is collected during research, and to be highly aware of this aspect during research analyses, discussion, and the possible use of the results.

Necessary training

Basic knowledge in botanical and social science methods are equally important for ethnobotanical studies based on archival knowledge, literature, or field interviews. In order to communicate with and understand local experts, it is mandatory to have some sort of training in botany, even if the researcher's background is in social science. Without botanical knowledge it will be impossible to understand which plants people are talking about. It is also necessary to be able to identify plants in the field, to understand when different names are used for one plant and in general to be able to ask relevant questions. It is equally important that the researcher, if they have a background solely in natural sciences, learn basic skills and techniques of social sciences. For example, being able to conduct high quality interviews with individuals or groups of local people, or spending prolonged periods of time within a local community (e.g. participant observation), and invaluable to gather data on plant use in certain areas.

Conclusions

Ethnobotany is a multifaceted research field, deeply interdisciplinary and often transdisciplinary involving local experts in rural communities. The researcher conducting ethnobotanical research will develop skills about humans, nature and their relationships through time, which is a very rewarding, however complex field of knowledge. Ethnobotany is an important part of Historical Ecology, where it can contribute with research methods and human-nature insights on a level of detail that few other disciplines work with. The use of plants by indigenous and rural communities for food production, medicine or other economic and cultural activities can show the extent to which these societies depended on natural resources for their development and at the same time how they have influenced nature. Ethnobotany can be an invitation to a more intimate relationship between people and species other than humans, which is not the least important both for sustainable development, nature conservation and cultural heritage. Simultaneously, the information recorded by ethnobotanical research can be considered as historical documents telling us about the knowledge of certain communities in the present and/or the past.

References

Anderson, E.N. (2016). Ethnobiology and the new environmental anthropology. In: H. Kopnina, E. Shoreman-Ouimet (eds.), Routledge Handbook of Environmental Anthropology. London, Routledge.

Axelsson Linkowski W., Kvarnström, M., Westin, A., Moen, J. & Östlund, L. (2017). Wolf and bear depredation on livestock in northern Sweden 1827–2014: combining history, ecology and interviews. Land 2017, 6(3), 63; doi:10.3390/land6030063

Albuquerque, U.P., Ramos, M.A., Ferreira Júnior, W.S. & de Medeiros, P.M. (2016). Ethnobotany for beginners. Springer briefs in plant science. Springer, Cham, Switzerland.

Babai D. & Molnar Z. (2016). Species Rich Mountain Grasslands Through the Eyes of the Farmer: Flora, Species Composition and Extensive Grassland Management. Martor 21, 147–169.

Balée, W. (1994). Footprints of the forest: Ka'apor ethnobotany – The historical ecology of plant utilization by an Amazonian people. New York, Columbia University Press.

Balick, M.J., Cox, P.A. (1996). Plants, people, and culture. The science of ethnobotany. New York, Scientific American Library.

Berkes, F. (1993). Traditional ecological knowledge in perspective. In: J.T. Inglis (ed), Traditional knowledge. Concepts and cases. International Development Research Centre, Ottawa, Ontario, p. 1–9.

Berkes, F. (2008). Sacred Ecology. Second Edition, Routledge, New York.

Bexultanova, G., Prakofjewa, J., Sartori, M., Kalle, R., Pieroni, A. & Sõukand, R. (2022). Promotion of Wild Food Plant Use Diversity in the Soviet Union, 1922–1991. Plants. 11. 2670. 10.3390/plants11202670.

Bocşe M. & Mihaiu L.(1995). Medicina populară argument al ştiinţei şi al spiritualităţii româneşti. Marisia XXIII-XXIV. Studia Scientiarum Naturae Fascicola 2, Muzeul Judeţean Mureş, p. 235-334.

Brody, H. (1981). Maps and dreams: indians and the British Columbia frontier. Vancouver: Douglas & McIntyre

Brøndegaard, V.J. (1978–1980). Folk og flora: dansk etnobotanik. Köpenhamn: Rosenkilde og Bagger.

Burton, R.J.F. & Riley, M. (2018). Traditional Ecological Knowledge from the internet? The case of hay meadows in Europe. Land Use Policy 70, 334-346, https://doi.org/10.1016/j.landusepol.2017.10.014.

Carroll, C., Garroutte, E. Noonan, C. & Buchwald, D. (2018). Using PhotoVoice to Promote Land Conservation and Indigenous Well-Being in Oklahoma. Ecohealth 15(2), 450–461. doi:10.1007/s10393-018-1330-9.

Clément, D. (1998). The historical foundations of ethnobiology (1860–1899). Journal of Ethnobiology 18(2):161–187.

Cotton, C.M. (1996). Ethnobotany: principles and applications. John Wiley & Sons, Chichester – New York – Brisbane – Toronto – Singapore.

Cunningham, A.B. (2001). Applied ethnobotany: People, wild plant use & conservation. Earthscan Publications, London & Sterling, VA.

D'Ambrosio, U. (2014). Theoretical reflections on ethnobiology in the third millennium. Contributions to Science 10:49–64. doi:10.2436/20.7010.01.188

Dedrick, M. (2018) Photovoice as a method for the development of collaborative archaeological practice, Journal of Community Archaeology & Heritage, 5:2, 85-100, DOI: 10.1080/20518196.2018.1442659

Fontefrancesco, M.F., Zocchi, D.M. & Cevasco, R. (2022). Crumbotti and rose petals in a ghost mountain valley: foraging, landscape, and their transformations in the upper Borbera Valley, NW Italy. J Ethnobiology Ethnomedicine 18, 42 https://doi.org/10.1186/s13002-022-00535-7

Ford, I.R. (2011). The History of Ethnobiology. In: E.N. Anderson, D. Pearsall, E. Hunn & N. Turner(eds), Ethnobiology. Wiley-Blackwell, Hoboken, NJ, p. 15–26.

Fraisl, D., Hager, G. Bedessem, B. Gold, M., Hsing, P.-Y., Danielsen, F., Hitchcock, C.B., Hulbert, J.M., Piera, J. Spiers, H., Thiel, M. & Haklay, M. (2022). Citizen science in environmental and ecological sciences. Natures Reviews Methods Primers 2, 64. https://doi.org/10.1038/s43586-022-00144-4

Harshberger, J.W. (1896). The purposes of ethno-botany. Botanical Gazette 21(3),101–184.

Herjulfsdotter, R. (2013). Mariaväxter i folktron. Skara: Skara stiftshistoriska sällskap.

Hilding-Rydevik, T., Moen, J. & Green, C. (2018). Baselines and the Shifting Baseline Syndrome – Exploring Frames of Reference in Nature Conservation. In: C.L. Crumley, T. Lennartsson, & A. Westin (eds.). Issues and Concepts in Historical Ecology: The Past and Future of Landscapes and Regions. Cambridge: Cambridge University Press.

Hunn, E. (2007). Ethnobiology in four phases. Journal of Ethnobiology 27(1):1–10. (https://doi.org/10.2993/0278-0771(2007)27[1:EIFP]2.0.CO;2)

Høeg, O.A. (1976). Planter og tradisjon: floraen i levende tale og tradisjon i Norge 1925-1973. Universitetsforlaget.

Höft, M., Barik, S.K., Lykke, A.M. (1999). Quantitative ethnobotany. Applications of multivariate and statistical analyses in ethnobotany. People and plants working paper 6. UNESCO, Paris.

International Society of Ethnobiology, (2006) ISE Code of Ethics (with 2008 additions). Online: http://ethnobiology.net/code-of-ethics/)

Iuga, A. (2016), Intangible hay heritage in Şurdeşti. Martor 21, 67-84.

Ivaşcu, C.M., Öllerer, K. & Rakosy, L. (2016). The Traditional Perception of Hay and Hay-Meadow Management in a Historical Village from Maramureş County, Romania. Martor 21, 39-51.

Kvarnström, M. & Boström, J. (2018). Kalix archipelago: biodiversity, ecosystems, local knowledge and customary use, p. 31–63. In: H. Tunón (ed.). Nordic IPBES-like Assessment of Biodiversity and Ecosystem Services in Coastal Ecosystems. Vol. 2. Geographical Case Studies. TemaNord 2018:532. Copenhagen: Nordic Council of Ministers.

Leu, V. (1996). Cartea şi lumea rurală în Banat. Editura Banatica, Reşiţa.

Martin, G.J. (2004). Ethnobotany: a methods manual. Earthscan, Oxon, UK. & New York.

Mattalia, G., Stryamets, N., Pieroni, A. & Sõukand, R. (2020). Knowledge transmission patterns at the border: ethnobotany of Hutsuls living in the Carpathian Mountains of Bukovina (SW Ukraine and NE Romania). J Ethnobiology Ethnomedicine 16, 41. https://doi.org/10.1186/s13002-020-00391-3

Nolanc, M.J. & Turner, J.M. (2011), Ethnobotany: The study of people – plant relationships. In: E.N. Anderson, D. Pearsall, E. Hunn & N. Turner (eds), Ethnobiology. Wiley-Blackwell, Hoboken, NJ, p. 133-147.
Parker, C., Scott, S. & Geddes, A. (2019). Snowball Sampling. SAGE Research Methods Foundations. doi:10.4135/

Östling, Per-Anders (2010). Dialekt- och folkminnesarkivens material: etnobiologi på institutet för språk och folkminnen (SOFI): exemplet ULMA. In: H. Tunón & A. Dahlström. (eds.) Nycklar till kunskap: Om människans bruk av naturen. CBM:s skriftserie 34 & Skogs- och lantbrukshistoriska meddelanden nr 48. Centrum för biologisk mångfald, Uppsala & Kungl. Skogs- och Lantbruksakademien, Stockholm, 67-72

Pieroni, A. & Leimer-Price, L. (2006). Eating and Healing: Traditional Food as Medicine. CRC Press.
Pliny the Elder. 1855–1857. The Natural History. Vol 3. Henry G. Bohn, York Street, Covent Garden. Books XII–XIX. English edition. England. Available online in English translation: https://www.gutenberg.org/ebooks/author/50041.

Poudel, P. (2010). The use of a landscape. Perspective to assess the nature value of a traditionally managed landscape. Master thesis, EX0681. Swedish University of Agricultural Sciences, Uppsala.

Pretty, J.N. Guijt, I. Thompson, J. & Scoones, I. (1995). Participatory Learning & Action. A trainer's guide. IIED, London.

Reyes-García, V. Tofighi-Niaki, A., Austin, B.J. Benyei,P. Danielsen, F., Fernández-Llamazares, Á., Sharma, A., Soleymani-Fard, R. & Tengö, M. (2022). Data Sovereignty in Community-Based Environmental Monitoring: Toward Equitable Environmental Data Governance. Bioscience 72(8):714–717.

Ryd, Y. (2010a). Intervjuer – en metod att utreda stora kunskapssystem [Interviews – a method to discover large knowledge systems]. In: Tunón, H. & Dahlström, A. (eds.) Nycklar till kunskap om människans bruk av naturen [Keys to knowledge about the use of nature]. Kungl. Skogs- och Lantbruksakademien, Stockholm, p. 233–244.

Ryd, L. (2010b). Att arbeta med muntliga källor – intervjuhandledning [To work with oral sources – a manual for interviews. In: Tunón, H. & Dahlström, A. (eds.) Nycklar till kunskap om människans bruk av naturen [Keys to knowledge about the use of nature]. Kungl. Skogs- och Lantbruksakademien, Stockholm, p. 233–244.
Ryd, Y. (2009). Att upptäcka och samla in traditionell kunskap [To detect and collect traditional knowledge]. In: Westman, A. & Tunón, H. (eds.) Ju förr desto bättre [The sooner the better]. Centrum för biologisk mångfald, Uppsala, 59–80.

Schultes, R.E. & Von Reis, S. (eds.). (1995). Ethnobotany: Evolution of a Discipline. Dioscorides Press, Portland, USA.

Sõukand, R., Quave, C.L., Pieroni, A., Pardo-de-Santayana, M., Tardío, J., Kalle, R., Łucza,j Ł., Svanberg, I., Kolosova, V., Aceituno-Mata, L., Menendez-Baceta, G., Kołodziejska-Degórska, I., Pirożnikow, E., Petkevičius, R., Hajdari, A. & Mustafa, B. (2013). Plants used for making recreational tea in Europe: a review based on specific research sites. Journal of Ethnobiology and Ethnomedicine. Aug 13;9(1):58. doi: 10.1186/1746-4269-9-58.

Sutton-Brown, C.A. (2014) Photovoice: A Methodological Guide, Photography and Culture, 7:2, 169-185, DOI: 10.2752/175145214X13999922103165

Svanberg, I. & Łuczaj, Ł. (2014). Activity Contexts and Biocultural Domains. European Studies of Folk Biology. In: I. Svanberg & Ł. Łukasz. Pioneers in European Ethnobiology. Uppsala University Library, Sweden.
Thomas, E., Vandebroek, I. & Van Damme, P. (2007). What Works in the Field? A Comparison of Different lnterviewing Methods in Ethnobotany with Special Reference to the Use of Photographs. Economic Botany 61 (4), 376-384.

Tobias, T.N. (2000). Chief Kerry's moose – a guidebook to land use and occupancy mapping, research design and data collection. The Union of BC Indian Chiefs & Ecotrust Canada, Vancouver.
Treben, M. 1987. Health from God's Garden: Herbal Remedies for Glowing Health and Well-Being. Healing Arts Press.

Tunón, H. & Bele, B. (2019). Fäbod and seter. Summer farms on the Scandinavian peninsula. Swedish Biodiversity Centre, Uppsala.

Tunón, H. & Byström, M. (2010). "Etnokartering: att synliggöra naturresursanvändning", p. 285–296 In: H.

Tunón & A. Dahlström. (eds.) (2010). Nycklar till kunskap: Om människans bruk av naturen. CBM:s skriftserie 34 & Skogs- och lantbrukshistoriska meddelanden nr 48. Centrum för biologisk mångfald, Uppsala & Kungl. Skogs- och Lantbruksakademien, Stockholm.

Tunón, H. (2000). "Botemedel i samisk medicin" [Cures in Saami medicine], p. 126–163 in Samisk etnobiologi: Människor, växter och djur i norr [Saami ethnobiology: Humans, plants and people in the North]. Eds. I. Svanberg & H. Tunón. Studia ethnobiologica 10. Nya Doxa, Stockholm.

Tunón, H. (2005). Medicinalväxter [Medicinal plants]. In: H. Tunón, M. Iwarsson. & S. Manktelow (eds.), Människan och floran. Etnobiologi i Sverige 2. Wahlström & Wistrand, Stockholm, p. 395–408.

Tunón, H. (2015). ”Studiet av bruket av naturen: Ur etnobiologins historia”, p. 33–46 In: Etnobotanik. Planter i skik og brug, i historien og i folkemedicinen. Vagn J. Brøndegaards biografi, bibliografi og artiker i udvalg på dansk. Vol. 1–2. Centrum för biologisk mångfald, Uppsala & Kungl. Skogs- och Lantbruksakademien, Stockholm.

Tunón, H., Kvarnström, M. & Lerner, H. (2016). Ethical codes of conduct for research related to Indigenous peoples and local communities – core principles, challenges and opportunities, p. 45–67. In: A.-L. Drugge (ed.) Ethics in Indigenous Research – Past Experiences, Future Challenges Vaartoe/Centre for Saami Research, Umeå University.

Tunón, H., Kvarnström, M. & Roto, J. (2020). Kartläggning av sociala, kulturella, ekonomiska och ekologiska värden i Sunds kommun, Åland: Resultat från lokala dialogworkshopar. CBM:s skriftserie 118. Centrum för biologisk mångfald, Uppsala. Only PDF
https://www.slu.se/globalassets/ew/org/centrb/cbm/dokument/publikationer-cbm/cbm-skriftserie/kartlaggning_av_sociala-kulturella_cbm-rapport-118.pdf

Tunón, H., Kvarnström, M., & Malmer P. (2015). Report from the project: Indigenous and Local Knowledge in a Scoping Study for a Nordic IPBES Assessment. CBM:s skriftserie nr 96. Swedish Biodiversity Centre, Uppsala.

Tunón, H., Kvarnström, M., Boström, J. & Utbult Almqvist, A.-K. (2019). Continued use of ecosystems: Challenges for fishing and farming communities. Baltic Worlds XII 2, 40–49.

Tunón, H., Rytkönen, P. & Bele, B. (2020). Are there lessons to be learnt? A comparative study of ethical challenges between community-based participatory research and case studies (pp. 103–126). In T. Sokolova, G.L. Gallardo Fernández & F. Saunders (Eds.) Co-creating actionable science: reflections from the global North and South.Cambridge, UK: Cambridge Scholars Publishing.

Tunón, H., Pettersson, B. & Iwarsson, M. (ed.) (2005). Människan och floran. Etnobiologi i Sverige 2. Stockholm: Wahlström & Widstrand.

Vallès,J., Garnatje, T. (2016). A vindication of ethnobotany. Mètode. Science Study Journal 6, 22–27.

Wall, T. & Richette, C. (2010). Nordiska museets arkiv - en källa till etnobiologisk kunskap. In: H. Tunón & A. Dahlström. (eds.) Nycklar till kunskap: Om människans bruk av naturen. CBM:s skriftserie 34 & Skogs- och lantbrukshistoriska meddelanden nr 48. Centrum för biologisk mångfald, Uppsala & Kungl. Skogs- och Lantbruksakademien, Stockholm, 59-65.

CHAPTER 8

LANDSCAPE ARCHAEOLOGY

PAUL LANE, SCOTT MADRY, ELIZABETH JONES

This chapter introduces the methods and techniques of the discipline of archaeology in support of Historical Ecology research. Archaeology, the study of humans and their cultures through the analysis of their material remains, has a great deal to offer in this context, and is often a key component in many Historical Ecology projects around the world. Archaeology is sometimes viewed as a subfield of Anthropology, the study of us, Homo sapiens, in all our many complex aspects. In North America it is seen as one of the key fields of Anthropology, where in Europe and on other continents it is generally treated as a separate discipline and sometimes closely aligned with History or Classical studies. Archaeological research may also be conducted by scholars based in other academic departments, including Art History, Environmental Sciences, Classics, Ancient History, History, and Religious Studies, as well as by government bodies at all levels and commercial companies in the context of Cultural Resource Management (CRM).

Archaeological investigations, particularly at a landscape scale, when linked with palaeoecological and environmental data and/or historical records, can provide important spatial and temporal context for both continuities and changes in human-environment interactions which are key to Historical Ecology. The use of genetics and DNA, spatial statistics, Geographical Information Systems, and other digital tools such as airborne LiDAR have greatly enhanced the analytical power and scope of the integration of the different kinds of data generated by archaeological research. These include data derived from field surveys and excavations, topographic and spatial information, diverse types of 'ecofacts' (e.g., faunal remains, macrobotanical remains, and the soil matrix), other information exposed in the course of excavation or recorded during surveys, and bioarchaeological data obtained from diverse forms of scientific analyses (e.g. genetic and isotopic analyses of human and animal remains regarding past climatic and vegetation conditions, diet, migration, mobility patterns, and more). Archaeology is closely related to the disciplines of history, art history, and classical archaeology, as well as to geology, geography, chemistry, botany, zoology and ecology, and offers distinctive insights into long term trends and processes unavailable through other kinds of sources. Archaeology is inherently an interdisciplinary activity.

Introduction

The focus of archaeology is the discovery and analysis of human material culture or "artifacts," which includes anything made, modified, altered or used by humans. This includes artefactual, architectural and structural material remains above the ground as well as those long buried in the Earth. The methods of archaeology involve a complex series of aerial, documentary, and field surveys, the discovery, documentation, and analysis of artifacts and 'sites' located via these surveys, the careful excavation and documentation of more important (or simply better preserved) sites that may include multiple occupations over time, and the overall analysis of all of these into an integrated and holistic understanding of the patterns of human use of the landscape over time. Field surveys can take years, and can cover very large areas and record numerous cultural artifacts on the landscape such as roadways, structures, ritual sites, agricultural fields, villages, etc. Individual sites can be excavated, again possibly taking years, with the extraction, documentation, analysis, and curation of many thousands of material artifacts, including all of the items associated with human occupation and a variety of different types of environmental samples. Archaeological specialists in metals, textiles, human, animal and fish bones, shells, plant remains, stone, and ceramics analyze and preserve individual items, and all of this, together, must be synthesized into a coherent story that represents the temporal and spatial 'history' of an area and its inhabitants. Archaeology is a complex and multidisciplinary endeavor within itself, but it can be conducted within the larger, overall context where it is integrated with the other components within Historical Ecology that are presented in this volume.

Archaeology and the collection, analysis, and conservation of archaeological data has many unique aspects to it, due to the cultural and legal importance of archaeological artifacts and sites. Permits must be acquired for field survey, geophysical analysis, and excavation, and there are generally specific governmental restrictions on the disposition of all materials discovered, including human remains, including limitations on exporting artifacts for analysis. Archaeological site data are often considered confidential information, particularly in association with human remains or important cultural components that could be the subject of illegal artifact looting, which is a significant problem around the world. Each nation has its own legal framework for archaeology , and these must be understood and followed carefully. Artifacts must be properly curated, requiring dedicated facilities and expertise.

Archaeological Data Types

There are many types of archaeological artifacts, including:

1. Structures. 'Artifacts originally created to define space for human activities or to be used as components of space defining artifacts.'
2. Building furnishings. 'Artifacts originally created to facilitate human activity and to provide for physical needs of people generally by offering comfort, convenience or protection,' but not including clothing.
3. Personal artifacts. 'Artifacts originally created to serve the personal needs of an individual such as clothing, adornment, body protection, or an aid to grooming.'
4. Tools and equipment for materials. 'Tools, equipment, and supplies originally created to manage, oversee, capture, harvest, or collect resources and to transform or modify particular materials, both raw and processed.'
5. Tools and equipment for science and technology. 'Tools, equipment, and supplies used for the observation of natural phenomena or to apply knowledge gained from such observation.'
6. Tools and equipment for communication. 'Tools, equipment, and supplies used to enable communication,' but not including ' things produced as communication, such as works of art and documents.'
7. Distribution and transportation artifacts. 'Artifacts originally created to transport or distribute animate and inanimate things.'
8. Communication artifacts. 'Artifacts originally created as expressions of human thought,' including such things as advertising media, art, ceremonial artifacts, documentary artifacts, media of exchange (such as coins and currency), and personal symbols.'
9. Economic artifacts. 'Artifacts that are used for commerce, trade and exchange, including coins and money and storage vessels.
10. Military artifacts. 'Artifacts created for military purposes including earthworks, weapons, and armor'.

11. Religious, ritual and spiritual artifacts. 'Artifacts either deliberately created for the expression of religious, ritual or spiritual beliefs and purposes, or adapted to serve these ends.'
12. Recreational artifacts. 'Artifacts originally created to be used as toys or to carry on the activities of sports, games, gambling, or public entertainment.'
13. Unidentified artifacts. 'Artifacts originally created to serve a purpose that cannot be identified at the time the object is cataloged.' The subcategories are 'remnant,' 'function unknown,' and 'multiple use' artifacts.

Categories of Analysis

There are many types of analysis for these artifacts, including:
1. Material involves what the object is made of–woods, fibers, ceramic bodies, metals, glass, and so on.
2. Construction has to do with the techniques of manufacture employed, workmanship, and the way parts are organized to bring about the object's function.
3. Design includes the structure, form, style, ornament, and iconography of the object.
4. Function embraces both the uses (intended function) and the roles (unintended functions) of the object in its culture, including utility, delight, and communication.
5. Identification (including classification, authentication, and description).
6. Evaluation, which results in a set of judgments about the artifact, usually based on comparisons with other examples of its kind.
7. Cultural analysis, which examines the various interrelationships of an artifact and its contemporary culture.
8. Interpretation, which suggests the meaning and significance of the artifact in relation to aspects of our own culture." This includes relating an artifact to the others with which it was found or associated–i.e., its meaning in context of the "assemblage."

Archaeologists around the world have developed over the decades detailed chronologies of local cultural traditions based on these assemblages, including detailed lithic and ceramic (the two most durable and hence common classes of artifacts) typologies, for example, which allow the relative dating of an artifact and thus, the stratigraphic layer where it was discovered (O'Brien & Lyman, 2002).

For landscape studies, this includes a spatial analysis of the constructed landscape features and their relationship to each other, often undertaken within a Geographical Information System (GIS). Archaeological material culture analyses are a "people-centered, relational field of study, using material culture to comprehend aspects of everyday social life that often go unmentioned, or are obscured for varying ideological reasons." (Cochran & Beaudry, 2006).

In order to perform the above analyses of any artifact (e.g. dating, materials, stylistic components, etc.), archaeology has to be conducted as an inherently cross-disciplinary and team-oriented activity, involving specialists with many skillsets who work together to create a complete interpretation of the people and landscape which are being studied over space and time. These specialists can include bioarchaeologists, cartographers and photographers, faunal, wood, metal and lithic data specialists, geologists, art historians, remote sensing and GIS specialists, excavation specialists, field surveyors, a myriad of conservation specialists, artists, and others. Specialists in data recording and artifact curation are also required, and these large teams entail significant administrative, logistical, and financial support and hence, skilled project managers.

Archaeologists study bio-cultural behavior through the medium of material culture–that is, objects made or modified by humans. Biologically, they are interested in such things as the cognitive abilities that first enabled the manufacture and use of tools in early hominids. Culturally, they study artifacts as representative of economic, personal, social and symbolic behavior. It is important to note that Archaeology does not differ from sociocultural anthropology by being a study of the past. Archaeologists also study material culture in the present as well, with some studying modern garbage to learn about behavior in contemporary societies.

The discipline has evolved quite differently around the world. In North America, it is generally considered to be one of four subfields of Anthropology, along with cultural, biological, and linguistic studies. In several European traditions, archaeology stands distinct from anthropology and often has (or had) closer ties with History, and each European national tradition has distinct excavation approaches and methods which make international joint excavations challenging. Archaeology is very much a traditionally learned skillset, passed down from teacher to student, within a specific cultural context and approach to the work and forms of embodied behavior.

There are also several different sub-fields or sub-disciplines within archaeology. These can include historical archaeology, geoarchaeology, industrial archaeology, landscape archaeology, experimental archaeology, classical archaeology, biblical archaeology, and more. Each brings with it its own perspective, research traditions, and perception of the discipline and approach to data and analysis. Within each of these, many archaeologists may specialize in a subfield such as excavation, field survey, GIS, ceramics analysis, geo or eco-archaeology, or many others. It requires all of these, working in concert, to conduct a major project, and the management and synthesis of the many components is a key meta-level skill set of experienced project managers and senior scholars.

Archaeology is conducted within both quantitative and qualitative frameworks, and so the data, analysis, and conclusions are primarily conceived within these, depending in part on theoretical orientation and project goals. Archaeologists are very good at determining occupation dates, stratigraphic levels and contexts, ceramic types and traditions, and timeframes because of the nature of their empirical data which also lends itself to quantification. Qualitative questions of meaning, intent, personal relationships, spiritual practices, and social context are more challenging, and require careful attention to the various stages of inference involved in interpretation of archaeological data and their spatial and temporal patterning, and the multiple sources of bias that can shape such interpretations, including the wider political, social and even religious contexts in which archaeological research takes place (Wylie, 2002; Chapman and Wylie, 2006; Lucas, 2012).

Archaeological surveys, on land, from the air and even under water, provide information about past settlement patterns, resource utilization, transportation routes, and more at various spatial scales. Excavation of specific archaeological sites provides in-depth (pun intended) information about the chronology of use and occupation, and can include the collection of ceramics, bone, wood, soils, metal, pollen, materials for radiocarbon dating, and other information that further illuminates the history of use of that location. Surveys, on the other hand, tend to work on a larger spatial canvas, providing insights about the nature and changing distribution of activities across a large area but without the highly detailed information about each place that can be obtained via excavation. To illustrate these diverse methods and their application in Historical Ecological research, in this chapter we begin by briefly describing the characteristics of 'landscape archaeology', and its development as a distinct field within the wider discipline, and some of its key theoretical orientations and underpinnings. We then summarize the main types of analyses associated with different categories of archaeological data before presenting a case study from East Africa of the application of these approaches in Historical Ecological research. The chapter concludes with a short discussion of the applied value of archaeological data for addressing current and future socio-ecological and environmental challenges with reference to a selection of archaeologically driven Historical Ecology studies undertaken in different parts of the world.

Landscape Archaeology

The largest archaeological artifact is the landscape itself, which is modified over time to create built environments for habitation, and the associated material infrastructure to extract resources (such as mining ores or harvesting timber) or to grow crops, raise animals, and provide defense against enemies (Bruno & Thomas, 2008). The term 'landscape' however, has many connotations, both within individual disciplines and across them (Förster et al. 2013). As Monroe and Ogundiran (2012: 13) note, 'ask ten archaeologists to define 'landscape' and one will undoubtedly receive at least as many answers'. Landscapes are transformed both intentionally and unintentionally by human activities, with many of the unintentional changes having significant consequences as well as intentional ones, especially when assessed over the long-term - for example, the production of greenhouse gasses, including methane and carbon dioxide, from crop cultivation, livestock and burning fossil fuels. It is important to stress that not all human activities have negative consequences for an ecosystem or biodiversity, and a goal of archaeologically driven Historical Ecological research is often aimed at documenting both the positive and negative ways in which human actions have affected change at different spatial and temporal scales, from the site level to that of the entire Earth System.

Landscape definitions

Western scholarly definitions of landscape, and their corresponding contrasting methodologies and analytical approaches, have been conventionally construed in binary terms – with one approach focusing on the physical characteristics and properties of the land (such as geology, topography, vegetation, physical features etc.), and the other more concerned with how the landscape is viewed, perceived and understood. The intellectual roots of these contrasting traditions have been explored at great length in the literature (e.g. Cosgrove, 1984; Widgren 2004, 2015; Casey, 2008; Olwig, 2019), as have some of their contrasts with other traditions (e.g. Luig & Oppen, 1997; Shaw & Oldfield, 2007; Taylor, 2009). As many of these studies emphasize, the English word 'landscape' derives from the sixth century Anglo-German words 'landskipe' or 'landscaef', meaning "a clearing in the forest with animals, huts, fields, [and] fences' ' (Taylor, 2009: 10). As evident from this etymology, the term was originally intended to distinguish those places shaped by human activities from the surrounding 'wilderness', creating a distinction between 'nature' and 'culture'. In the Germanic, Dutch, and Scandinavian traditions these terms also referenced the customs and traditions associated with living in these cleared spaces, and the rights that a person's or community's presence in a defined territory conferred on them, especially their rights of access to resources and their management (Olwig, 1996; Widgren, 2004). The common French equivalent to the English word 'landscape' - paysage - has different etymological routes and hence connotations. Derived from the Latin 'pagus', "meaning a defined rural district" (Taylor, 2009: 10), the term implicitly lays more emphasis on the distinctiveness of particular areas of land arising from the long-term interplay between particular cultural traditions and the physical environment in which these take place (Chevalier, 1976; Marano, 2017). In the seventeenth century and emanating from changes in artistic traditions and the rise of landscape painting, new ideas about landscape emerged, emphasizing less how such spaces were lived in and managed and instead focusing on how landscapes were perceived and represented (Olwig, 1996). Drawing on this externalized perspective, some scholars argue that landscapes need to be understood as 'cultural images', "a pictorial way of representing, structuring and symbolizing surroundings" (Cosgrove & Daniels, 1988: 1).

Table 8.1. Different Concepts of Landscape (after Widgren 2004, with additions)

Conceptualisation	Key Components/Emphases
Landscape as scenery	Representation
	Idea/Mental Construction
	'A way of seeing', sensory engagement
Landscape as Institution	Customary law, governance structures
	Social order, land rights
	'A way of communicating, a way of acting'
Landscape as physical terrain	Topography and physical features (rivers, mountains etc.)
	Soils and vegetation cover
	Climatic regimes
Land(scape) as resource	Land use, biological production
	Production
	Capital, inc. landesque capital
Landscape as dwelling	Taskscapes
	Rhythm and temporality of activities
	'Being in the world', phenomenology

These are perhaps subtle distinctions but can help explain several of the varying connotations of the word 'landscape' and its equivalents in other Western European languages (Table 8.1), and the distinctiveness of different regional academic traditions of landscape history and archaeology. In France, for example, research in the early twentieth century was shaped especially by the ideas of the French geographer Paul Vidal de la Blache (who in turn drew on some of the ideas expressed by the German geographers Alexander von Humboldt and Friedrich Ratzel). His 1903 book Le tableau de la géographie de la France promoted an approach that became extremely influential among French researchers. This focused primarily on the cultivated elements of landscape rather than 'natural' landscapes, and on France's regional geographical diversity, the interrelations between people and their environments, and the influence of these on the formation of national identity (Claval, 1998). A somewhat similar sentiment is evident in the work of the American geographer Carl O. Sauer, who defined 'cultural landscapes' as places "fashioned out of a natural landscape by a culture group" (1925: 25). Sauer, however, is better known for his promotion of morphological approaches to the study of landscapes, especially their physical characteristics, although his work is also widely regarded as having laid the basis for historical cultural geography in North America, as came to be epitomized by the Berkeley school of geography (Williams, 1983). Within these traditions, a further contrast lies in the attention French geographers at the time placed on understanding lived, rural, essentially agricultural landscapes, whereas in North American thought and scholarship the idea of landscape was typically associated with 'natural' spaces and 'wilderness', and closely tied to preservationist movements aimed at conserving 'nature' (Henderson, 1992; Haila, 1997).

In many ways, this dualistic conception of landscape and approaches to the interpretation of particular landscapes is a reiteration of a deeper and more pervasive binary in Western, post-Enlightenment intellectual thought between 'Nature' and 'Culture' that continues to shape disciplinary perspectives and conservation and preservation practices (Cronon, 1996). As research informed by historical and political ecology across the globe has highlighted, while such divisions may have heuristic and practical value, the separation of humans from their environment and other, non-human co-inhabitants of those environments is, in the longer term, detrimental to the interpretation, understanding and management of landscapes and seascapes regardless of their particular characteristics and individual historical trajectories (Baleé, 1998, 2013; Crumley, 1994, 2021; Descola, 1996, 2014).

Palimpsests, Taskscapes, and Matters of Scale

Archaeological data can be analyzed at a range of scales, ranging from the micro-scale physical, chemical, morphological and/or stylistic properties of individual artifacts and ecofacts [a biological artifact not altered by humans, but which may be indicative of human occupation], to their contextual associations within distinct archaeological scatters, structural features and individual sites, and ultimately in terms of their wider distribution and patterning at the landscape scale. Archaeological research typically tacks back and forth between these different analytical scales (Clarke, 1977; Lock & Molyneaux, 2006), often with different specialists providing detailed insights on the nature of the data and archaeological information that can be extracted at one or other scale of analysis. Common concerns, regardless of the scale of analysis, are with the temporal and spatial dimensions of the data being analyzed and their contextual associations with both similar and other kinds of data. Much primary archaeological analysis is either object- or site-based. Scaling up to produce meaningful inferences about past human actions and social practices at the landscape scale presents various challenges, not least of which are identification of the diversity of processes that can lead to the formation of archaeological records and those which may influence their recovery for analysis (Schiffer 1987), as well as the temporal resolution of these records and the past activities that created them (Holdaway and Wandsnider 2008).

The most obvious reason for this is that landscapes (and also archaeological 'sites') are dynamic entities within which their individual elements and characteristics are continuously subject to modification, addition and/or loss as a consequence of a combination of human and other, non-anthropogenic actions and processes (Foley 1981). Hence, both landscapes and sites are often likened to palimpsests – something altered or reused that still retains traces of its earlier, original form and purpose. The English landscape archaeologist O.G.S. Crawford (1953) evoked this perfectly in his pioneering book Archaeology in the Field:

> The surface of England is like a palimpsest, a document that has been written on and erased over and over again; and it is the business of the field archaeologist to decipher it. The features concerned are of

> course the roads and field boundaries, the woods, the farms and other habitations, and all the other products of human labour; these are the letters and words inscribed on the land. But it is not easy to read them because, whereas the vellum document was seldom wiped clean more than once or twice, the land has been subjected to continual change throughout the ages. (Crawford 1953: 51–2).

W.G. Hoskins, widely regarded as the pioneer of English Landscape history (and who was certainly influenced by Crawford's approach) similarly wrote about the English landscape as 'a palimpsest, written upon again and again', although he preferred his own metaphor, likening the landscape to a symphony, best appreciated less 'as an architectural mass of sound' and more by trying to isolate 'themes as they enter, to see how one by one they are intricately woven together and by what magic new harmonies are produced', going on to argue that '[o]nly when we know all the themes and harmonies can we begin to appreciate [a landscape's] full beauty, or to discover in it new subtleties every time we visit it' (Hoskins 1955: 19).

The idea that landscapes and individual sites are comprised of the material traces of successive layers of activity, each adding to and removing from the traces that had existed previously was equally a guiding feature of the research by the North American archaeologist Lewis Binford, albeit his accounts were far less poetically expressed or evocative of place than those by Crawford or Hoskins. One of the clearest examples provided by Binford is in his account of the progressive formation of 'archaeological' sites over several seasons and even generations of activity by mobile Nunamiut hunter-gatherers in northern and north-western Alaska, especially Anaktuvuk Pass (Binford, 1982). In this 'archaeology of place', Binford describes how the purpose or 'function' of different places within this landscape could change as the distribution of activities changed in response to the seasons, or as the routes followed by Nunamiut to track caribou or access other wild resources shifted and the locations of their home bases were moved. In one example, for instance, Binford (1982, 12-14) describes how a residential camp was established at the junction between a major river and tributary in a location that had previously been used as a transient camp/rest stop. Over the next few months, various hunting parties, fishing and trapping groups and other work groups moved out from this residential camp into the landscape creating a 'logistical' task zone, with some returning the same day and others spending several nights and even weeks away from their base.

Each of these activities left different kinds of material traces in the landscape associated with the tasks performed, and also influenced by the time spent in each locality and the size of the task group. As the distribution of resources altered in response to the changing seasons, the group eventually moved their base camp to another part of their wider territory, and the spatial distribution of their various off-site activities also changed. As part of this change, the former residential site was now used as a hunting camp, occupied only by men who performed a restricted range of tasks compared with those undertaken in the same locality just a few months previously. In other words, over the span of no more than a few years, a particular point in the landscape was the focus of different kinds of activities (temporary rest camp, seasonal residential camp, short term hunting camp), each generating different kinds of material traces, differing also in terms of spatial patterning and density of discarded materials. Over time, the same place might be used in similar or different ways, each time newly deposited items accumulating over older deposits and blending into one another to create a palimpsest of material traces.

As this example indicates, the notion that archaeological sites and landscapes are palimpsests, subject to regular 'blurring' of the spatial resolution of past human activities by both subsequent human activities and multiple non-anthropogenic processes that drive erosion and deposition, has obvious implications for understanding the temporal resolution of archaeological data. This is not just because over time material traces that were once temporally distinct can come to be stratigraphically associated with each other through the actions of different erosional or sedimentary events, but also because the very processes that contribute to the formation of archaeological records operate at different temporal rhythms from the very slow rates of 'geological' time to the much faster (and temporally briefer) rates of 'human' time. Geoff Bailey (1983, 2007) has referred to this as 'time perspectivism', on the grounds that when material traces are viewed according to different timescales, this brings different aspects of human behavior into focus and consequently requires different explanatory frameworks. For example, when approaching the interpretation of archaeological deposits and materials generated by activities only a hundred or so years ago, it may well be possible to approach their interpretation (partly because of possible cultural continuities linking these items with contemporary living communities, and also because of possible access to other supplementary sources - such as historical texts) in broadly anthropological and sociological terms. By contrast, when dealing with deposits formed tens of thousands of years ago, that have been subject also to repeated blurring as a consequence of diverse taphonomic processes, and by human communities very different from any living today, anthropological and sociological readings of the evidence may be far more challenging than interpreting the observed patterning from evolutionary and environmental perspectives. Bailey (2007: 201-3) also noted that different phenomena may operate at different rates and over different time spans, with some processes such as individual human agency and inter-personal interactions being both relatively rapid and of short-term duration compared with, for instance, geomorphological processes or phases of climate change which typically operate at very slow rates of change over the long term. Most archaeological contexts are the outcome of multiple processes and actions operating at different rates and durations, and archaeological sites comprise multiple contexts, some of which manifest as 'true palimpsests', i.e. 'a sequence of depositional episodes in which successive layers are superimposed on preceding ones' (Bailey, 2007: 204), while others are what Bailey terms 'cumulative palimpsests', i.e. layers marking 'successive episodes of deposition … that are so re-worked and mixed together that it is difficult … to separate them out into their original constituent' phases (ibid.).

Although most commonly considered with reference to the depositional setting in which archaeological materials are recovered during excavation and their attendant associations with other material 'things' and traces, at a landscape scale 'context' can also be approached via the concept of 'taskscapes', introduced into the archaeological literature by the British social anthropologist Tim Ingold (1993). To illustrate the concept, Ingold focused on a painting by Breughel the Elder known as The Harvesters, painted in 1565. The painting, thought to have been originally one of a series of twelve, each illustrating the seasonal activities associated with a particular month of the year, 'depicts the month of August, and shows field hands at work reaping and sheafing a luxuriant crop of wheat, whilst others pause for a midday meal and some well-earned rest' (Ingold, 1993: 165). In his analysis of the content and composition of the painting, Ingold exposes the ways in which different elements are connected, in both space and time, each dependent on each other and the connections between them for their specific manifestation and for being brought into being. For Ingold, the landscape is thus something that is always in the process of becoming, constantly reformed as the relationships between people and other elements of the landscape change, and are reconstituted through the intersection of place, time, and embodied practices. From this perspective 'landscape' can be understood as 'the world as it is known to those who dwell therein, who inhabit its places and journey along the paths connecting them' (Ingold, 1993: 156). In subsequent work, Ingold (2015) has expanded his analyses of paths and the networks of both physical and symbolic relationships these give rise to, characterizing landscapes as 'meshworks', and the social lives they encapsulate as being lived 'along lines of becoming'.

In contrast to the notion of landscapes being formed through processes of steady accumulation, aggregation and periodic erasure over time, a 'dwelling perspective' demands a rather different approach that emphasizes the embodied, experiential features of task performance and 'being' in a landscape. The adoption of the concept of 'taskscapes' and dwelling perspectives in archaeology (for a summary of their impact, see Rajala and Mills, 2017), has also encouraged some researchers to develop phenomenological approaches to understanding ancient landscapes. Key aspects of such approaches include the attention given to trying to recreate or at least mimic the embodied, sensorial experiences of being in and part of past landscapes, and how these change depending on the timing and tempo of activities, spatial orientation, direction of movement and other variables (Tilley, 1994). Such studies are always particularistic rather than generalizing in nature, and also highly personal as each of us experience landscapes colored by our own worldviews and biographies, yet, in many early studies the subjectivities of the modern researcher were often left unspecified or problematized (Brück, 2005; Johnson, 2011). Critics of phenomenological approaches have also highlighted that the landscapes experienced by a participant-observer today are never exact replicas of those that were lived in and created in the past, even if some elements have remained largely constant. Regardless of whether phenomenological understandings of modern landscapes also provide insights into how landscapes were created, used, understood and experienced in the past, an important implication of these debates, especially for integrating landscape archaeology into Historical Ecology, is that dwelling, as argued by Julian Thomas (2008: 302) drawing on the work of the German philosopher Martin Heidegger, is inherently 'a relationship with the world characterized by equanimity, in which one cares for and preserves one's surroundings while also allowing them to be themselves' (original emphasis).

Among the other characterisations of landscape archaeology, of particular relevance here are those that view landscapes and their ecologies, as political manifestations writ both small and large. Small, in the sense that to some degree all actions that take place on landscapes and through the affordances they offer are shaped by and contribute to their political context, and large in the sense that those with greatest political power are typically best placed to control the material form of any given landscape, and often normally hold greatest responsibility for directing their transformation and modification and control over who has access to resources on the land and even to land itself. Conversely, those with least overt political power may find themselves having to conceal their activities or even their presence from those in authority leaving minimal physical traces and material transformations, occupying 'empty spaces' and 'marginal' lands, although they may not conceive of such areas in these terms. Archaeological approaches to the study of political relations at the landscape scale, until recently, have tended to focus on the more monumental manifestations of power such as commonly found in state-level societies, ranging from burial structures built for members of the elite (such as pyramids) and palace and temple architecture, to various kinds of large-scale infrastructure such as road and irrigation systems, defensive walls and ditches, and planned settlements (Smith, 2003; Ashmore, 2004; Isbell, 2006; Falconer and Redman, 2009). As Sinopoli and Morrison (1995; see also Morrison and Lycett 1994) note, citing the example of the Vijayanagara empire (c. 1340-1648 CE) in southern India, inferring the nature of actual past political relations from these monumental 'statements' of power, is perhaps less straightforward than it might seem at first glance. Specifically, whereas the Vijayanagra capital, located close to the imperial frontier at the northern extent of the empire, exhibited many of the architectural characteristics commonly associated with political elites, these features, as well as the capital's geographical location and those of many satellite settlements also had sacred associations with the Hindu deities Rama and Shiva, while in outlying areas temples and localities formerly associated with local deities were also incorporated into the pantheon as part of a strategy aimed at symbolic unification of an ethnically and religiously diverse population. Similarly, while the territories beyond the capital saw the construction of large-scale irrigation systems, reservoirs, terracing and other forms of landesque capital geared toward agricultural intensification entailing access to large labor forces for their construction, both the archaeological evidence and limited historical sources suggest these were typically under the control of local authorities rather than a central elite.

As this example highlights, different kinds of power may be dispersed across the landscape, with different groups having different levels of allocative power over resources and variable scales of authoritative power over people and space. A critical concept to have emerged in discussions around such issues is that of 'heterarchy', as initially explored in landscape Historical Ecology with reference to the shifting political dynamics from the pre-Roman Iron Age onward evident in Burgundian landscapes in east-central France (Crumley 1987, 1995). In broad terms, heterarchical systems stand in contrast to hierarchical ones in which elements can be ranked such that some stand in subordinate relations to more dominant elements. Heterarchy, on the other hand, refers to the kind of relations that exist between different elements 'when they are unranked or when they possess the potential for being ranked in a number of different ways (Crumley, 1995: 3). Further elaborations of the concept with reference to the links between cultural landscapes and power have highlighted that many landscape exhibit a continuous spectrum of different power relations, encompassing the interests and actions of those with 'power over' others, those who hold 'power with' other people, and those, as members of subordinate groups, exercise 'power under' more dominant authorities (Spencer-Wood, 2010). Historical landscape archaeology has proved a fertile ground for the examination of such distinctions and their material manifestations (or lack, thereof), stimulating research on such diverse topics as elite gardens, the landscapes of enslavement and other underclasses, carceral landscapes, and landscapes of colonization and resistance (for reviews, see Branton, 2009; Spencer-Wood and Baugher, 2010), albeit with as yet limited consideration of how contrasting power relations shape the historical ecologies of different landscapes.

Common Archaeological Methods

There is no specific method that is unique to landscape archaeology, and in many ways the field can often serve as a model for reconstructing the Historical Ecology of a particular region or subregion, as most studies typically adopt a mixed method approach that employs (to greater or lesser extents depending on the temporal, geographical and thematic focus of the project) different archaeological datasets (such as from excavations, ground surveys, earthwork mapping, and geophysical surveys), documentary and cartographic sources, aerial photography and other remote sensing data, oral histories and placename data, geoarchaeological and bioarchaeological analyses, palaeoecological records, repeat photography, and even historical literary sources, among others, and integrating these into a dedicated project Geographical Information System (GIS). Some of the more commonly used methods and approaches are briefly described below, while further information on implementing these are available in numerous practical guides and handbooks (e.g., Aston, 1985; Aston & Rowley 1974; McMillon, 1991; Maschner and Chippindale, 2005; Hester, et al. 2009; Burke, et al. 2009; Carver, 2009; Burke, et al. 2017; Jamieson, 2017).

Survey

Field surveys are often the first step in a regional archaeological project. Very large areas can be covered by trained survey crews, looking for ceramics, lithics and other artifacts on the ground surface and in exposed sections, along with other landscape signatures of human occupation such as terraced fields, sunken roadways, canals, etc. There are multiple methods used (systematic vs. random), depending largely on the ground cover and project goals, and these surveys are often informed by aerial photos and can include low-level aerial survey by aircraft or, more commonly in recent years, low-cost drones and also high-resolution satellite imagery, including Google Earth (Madry 2007). The data collected are generally entered into a GIS platform to map the spatial distribution of artifacts in relation to other elements of the landscape. A field survey often leads to selective sampling using geophysical remote sensing, which can further identify potential locations for excavation. There are multiple issues that a well-planned survey needs to take into consideration so as to enhance the reliability of the results. These include the overall sampling design and methodology; monitoring the visibility of surface remains due to variations in ground cover, weather conditions and the experience of individual fieldworkers; and the possible distorting effects of natural and human processes and activities since materials were deposited or structures were created (Banning, 2002; Richards, 2008).

Figure. 8.1. An example of a field survey, conducted on the Greek island of Kythera, 15 meter field survey transects at left, and a map of the distribution of one type of diagnostic ceramics at right (https://www.kythera-family.net/en/academic-research/archaeology/archaeological-survey-methods-and-preliminary-results and https://www.austriaca.at/0xc1aa5576%200x003c7f51.pdf).

Archaeological Geophysical Remote Sensing

Once potential sites have been identified, or simply as a component of survey, a variety of geophysical techniques are available to further identify sites of interest (Cheetham, 2008). These are all non-destructive technologies and can provide a detailed set of images below the surface. Common methods include Ground Penetrating RADAR (GPR), magnetic gradiometer surveys, electrical resistivity, and electromagnetic conductivity (Gaffney and Garter, 2003; Comer and Harrower, 2013).

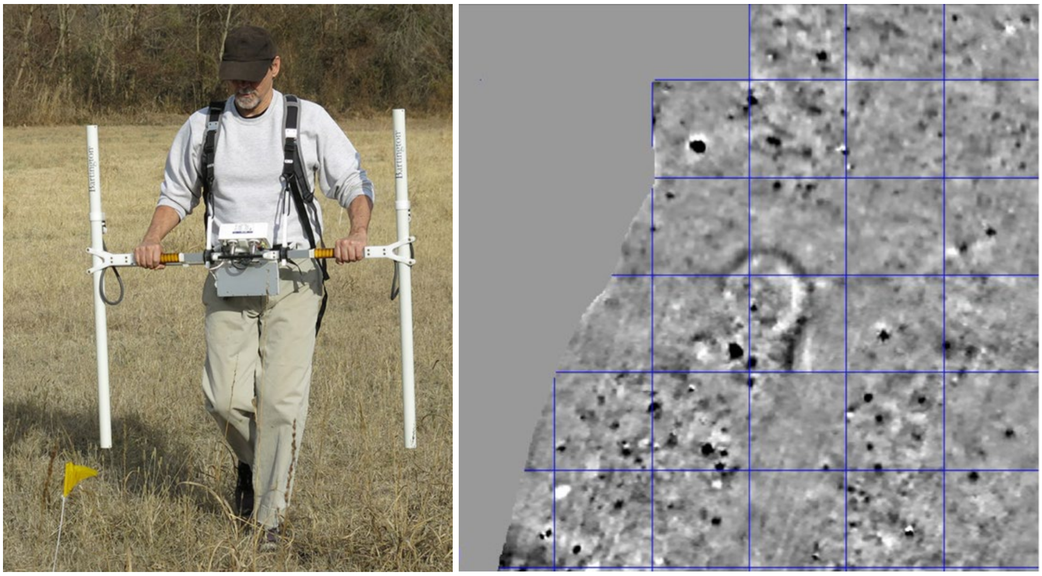


Figure. 8.2. Dr. Jamie Lockheart of the Arkansas Archaeological Survey doing a gradiometer survey, and some of the results indicating magnetic anomalies of a prehistoric village site in Arkansas. (https://archeology.uark.edu/learn-discover/current-research/arvgeophysicalsurvey/)

These several geophysical surveys, preferably used together, provide a detailed and non-invasive view of the soil layers beneath the surface, and can not only indicate artifacts such as pottery, burials, or building stones, but also indicate other evidence of human occupation such as fire hearths, water channels, and agricultural terraces. Constant improvements in these technologies and in the digital image processing of the data, have made it possible to conduct cost-effective, detailed surveys of large areas, and the data can be integrated into a project GIS system (Chapman, 2006; Connolly and Lake, 2006; Witten, 2006; Cattoor, et al. 2019).

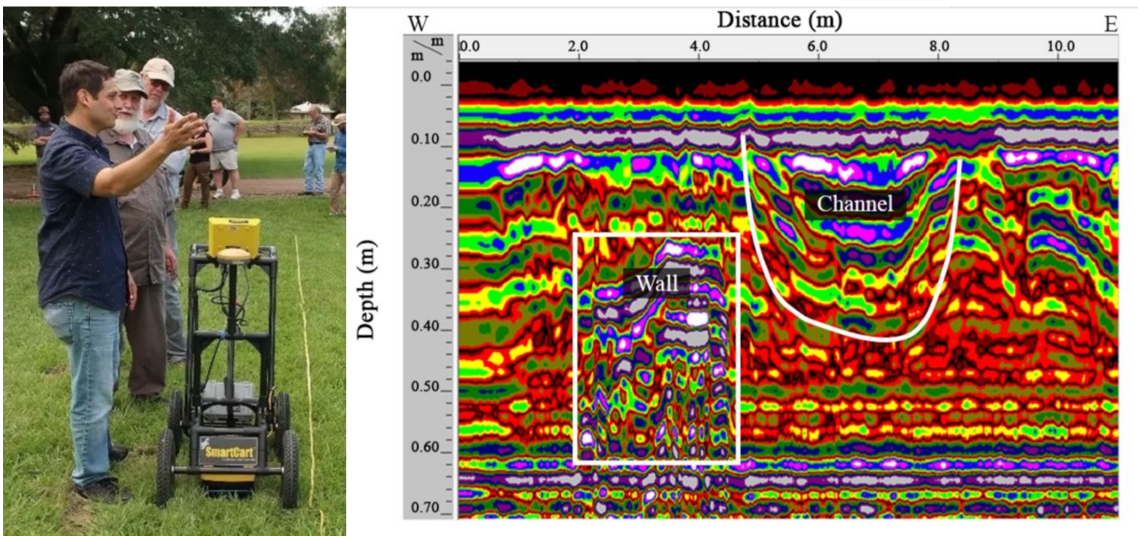


Figure 8.3. A GPR system (image courtesy U.S. National Park Service) https://www.nps.gov/articles/000/preservation-in-practice-gpr.htm) and a Ground Penetrating RADAR (GPR) underground profile of a buried wall and channel in Jordan (AbdEl-Rahman Abueladas and Akawwi 2020)

Excavation

Excavation is the bread and butter of archaeology and involves the detailed analysis of a structure or site through the destructive removal of all soil, dirt, rocks, and other matter which has buried the feature (Molyneaux, et al. 2003; Carver, 2009). The geological law of superposition generally means that upper stratigraphic zones nearer the surface are more recent (unless otherwise disturbed and inverted), and that as we excavate down we are exposing deposits and materials formed earlier and earlier in time.

Figure 8.4. The various stratigraphic layers in an excavation bulk of a site in Augsburg, Germany. These are not normally outlined in this way, but this example more clearly shows the differences in the several layers. (https://en.wikipedia.org/wiki/Archaeological_excavation).

Excavation provides us with the most detailed information of an area or site, but it is a destructive process, and once a site is excavated, it has been irrevocably altered, hence the emphasis placed on detailed and as comprehensive as possible recording of the deposits, contexts and materials encountered and the relationships between them (Barker, 1993; Roskams, 2001). All materials are carefully mapped in situ during the excavation process, using hand drawn plans, digital images, GPS, or a theodolite, and detailed maps are created to document the process, again, as the site is essentially destroyed in the process. Profiles (also called 'sections') through deposits are also drawn, photographed and described in detail, and often sampled for soil analysis and recovering macro botanical and faunal remains. All artifacts (metal, coins, bone, textiles, ceramics, wood, glass, etc.) that are removed are first mapped in situ with particular attention paid to their three-dimensional spatial relationships with one another and the context in which they were found and are then carefully analyzed to extract the maximum amount of information before their permanent curation. Specialists in the analysis and curation of these artifacts and the soil they were in provide vital information about the human occupation of the site, and the excavation of many sites in an area create a landscape view of that occupation.

Archaeobotany, Dating, Dendrochronology, Ecofacts, and Environmental Reconstruction

Once a site has been excavated, the soil and artifacts can be processed to conduct a wide range of analysis. Carbon 14 and other methods provide us with accurate dating of wood or other previously living materials. Preserved wood can also be analyzed using dendrochronology, as presented in Chapter 4. Soils can be analyzed and various 'ecofacts' such as phytoliths provide vital information about the state of the environment, vegetation, sources of food, and climate at the time of that occupation level in the site. All of these, together, provide vital information about the environmental context of each level of occupation and help to create a temporal and spatial component that can extend back many thousands of years.

Repeat Photography

As the term suggests, repeat photography involves taking photographs that are framed in such a way as to duplicate the view captured on a photograph taken some years previously. The technique generally relies on comparing and contrasting several oblique images of a particular landscape to identify changes in vegetation cover, visible signs of human activities and land use, and similar features that have occurred during the intervening years between each initial and repeat photograph. There are no precise guidelines as to the number of years separating the initial and repeat photographs, but most applications of the technique aimed at contributing to the reconstruction of the historical ecology of a particular landscape have tended to select the earliest known examples of photographs of the study area, which in some cases may have been taken over a century ago—as for example in some studies of landscape changes in Yellowstone National Park and in the American Southwest (e.g. Hastings and Turner, 1965; Meager and Houston, 1999). Identifying and locating relevant historical photographs that capture views across particular landscapes is the first step in undertaking such a study. National and state or county level archives, as well as those held by museums, mission societies, professional organizations such as the Royal Geographical Society of London, universities and other similar bodies are best consulted first. Local residents of the study area, especially those whose families have lived in the vicinity for generations may also have their own personal photographic collections. In other instances, historical picture postcards may prove equally useful (see chapter 2). Having identified possible historical photographs and obtained copies, the next, and often hardest step is try to relocate precisely where in the landscape the picture was taken. While precise matches are not always necessary, if the aim is to just present a generic view of how the landscape has changed over time, some studies require very precise matches. Historical photographs with good accompanying metadata on when and where they were taken, are especially valuable in this regard. For other photographs, the researcher may have to spend considerable time moving around a landscape trying to relocate the point in the landscape where the original photographer stood. Local informants, with knowledge of the landscape and changes to it can be very helpful contributors to this task. In framing a repeat photograph, three further steps need consideration (Kull, 2005; Klett, 2011). These are as follows: i) ensuring the camera lens replicates the same field of view as the original photograph, and as older photographs were commonly taken using wide format cameras, wide angle lenses are generally needed (somewhat easier with modern, digital cameras); ii) framing the repeat photograph so that it captures the same parts of the landscape and at an approximately similar scale as the original - this may be harder than it seems if there have been changes (vegetation growth, building construction, etc.) in the area where the original photographer stood; and iii) capturing similar lighting and seasonal conditions as those in the original photograph, given changes to these can make certain landscape features either less or more visible. Georeferencing the point where photographs are taken using a GPS receiver is also an important step, which will also help future researchers should they wish to replicate the study further.

Repeat photography, or rephotography as some prefer to name the technique (e.g., Klett, 2011), typically relies on qualitative analysis of a series of paired photographs taken at various points across a landscape that provide oblique views of vegetation cover, settlements and other landscape features whether 'natural' or anthropogenic. Many studies draw on supplementary sources, such as contemporary written descriptions (sometimes by the photographer her/himself), archival sources and oral information from modern informants. The technique also lends itself to integration within citizen science projects, which have the potential to generate more personal and embodied narratives of change unavailable to outside observers (Scott et al., 2021). More recently, various computer-aided approaches to quantitative analyses of the changes, often supplemented by reference to vertical imagery (aerial photographs, satellite images) have been developed (Bayr, 2021). Computational approaches have also begun to be developed for finding the location of historical photographs (Gilbert et al., 2023), although these seem best suited to locations where there is a fairly high density of historical photographs taken over several years to draw on for comparison.

Figure 8.5. Repeat photographs of the same view across the Lolldaiga Hills, Laikipia Plateau, Kenya in 1935 (left) and 2002 (right). Note the expansion of tree cover and encroachment of Acacia shrubland over what were once large, open grazing lawns.

Some of these changes may reflect changes in land management, but also replicate changes in land cover across the Laikipia Plateau since the 1940s. Several of these open areas mark the location of former pastoralist settlements, likely occupied in the 17th to late 19th centuries CE. Photo credits: left: D. Hinde, courtesy Robert Wells; right: Laragh Larsen for the British Institute in Eastern Africa.

Indigenous/Traditional Ecological Knowledge (I/TEK)

'Traditional Indigenous knowledge can be defined as a network of knowledges, beliefs, and traditions intended to preserve, communicate, and contextualize Indigenous relationships with culture and landscape over time' (Bruchac, 2014: 3814), along with Traditional Ecological Knowledge, constitutes a subset of such knowledge relating to the natural world and practical applications of Indigenous Knowledge regarding the management and stewardship of ecological resources and ontological characterisations of human-environment relations (Bruchac, 2014: 3816). As presented in chapters 3 and 7 of this volume, archaeologists routinely work together with local inhabitants and seek to understand modern Indigenous/Traditional Ecological Knowledge for a variety of purposes, including archaeological site detection, reconstructions of land use histories and resource use, and assessments of local heritage values and land management practices. As noted by Stump (2013), these knowledge systems like any other are subject to change over time, and it is important, especially in Historical Ecological research, not to treat I/TEK as ahistorical or timeless, and while incorporation of insights drawn from Indigenous communities is important for both practical and ethical reasons (Gadgil et al. 1993; Wolverton et al. 2023), critical assessments of their histories also need to be undertaken if the knowledge conveyed is to be used effectively in promoting sustainable development and socio-ecological resilience (for examples of such assessments, see e.g., Stump, 2010, 2019).

Synthesis

The final goal of an archaeological project is the synthesis of all the individual components of the work into a coherent and understandable story which accurately describes what we have learned (and still do not know) based on the work conducted. This synthesis is the ultimate goal of all the work of the many specialists and can be likened to an orchestra conductor integrating all the instruments into a single symphonic entity. Comparisons with previous projects and local knowledge allows the new work conducted to be placed into the local context and, hopefully, extends the total understanding of the region in both space and time from the perspective of the humans who lived there. New discoveries are put into their context, new theoretical questions are advanced, and additional hypotheses and future directions are presented.

Case Study: Integrated Landscape Analysis of the Nineteenth Century Caravan Trade in Eastern Africa

To better illustrate the kind of integrated landscape analysis (Lindholm & Ekblom, 2019) becoming increasingly common in archaeology, the following section provides an overview of the approach and methods employed to develop an outline historical ecology of the nineteenth century caravan trade in eastern Africa following escalation in demand for elephant ivory from the region from c. 1840 CE onward to the early twentieth century. This research formed the basis of a four-year landscape archaeology and historical ecology project (Historical Ecologies of East African Landscapes – HEEAL), hosted by the University of York, UK, and funded initially by a European Union Framework Programme 6 (FP6) Marie Curie Excellence (EXT) grant that ran from 2007 to 2013 (Lane, 2010). The research undertaken under the auspices of the HEEAL project was later augmented by additional research by Louise Iles funded by a European Union FP7 Marie-Curie International Outgoing Fellowship (EnvIron) hosted by the University of York and the University of Arizona between 2013 and 2015 (Iles et al., 2018). The project team also worked closely with another FP6 Marie Curie EXT project (York Institute for Tropical Ecology – KITE) also hosted at the University of York that was undertaking palaeoecological studies at various sites across the Eastern Arc mountains in Tanzania and Kenya, including those within the HEEAL study area (e.g. Mumbi et al., 2008; Marchant et al., 2009; Finch and Marchant, 2011; Finch et al., 2016).

The goals of the Historical Ecologies of East African Landscapes (HEEAL) project were to investigate the archaeological and historical signatures of the last 500 years of human settlement in eastern Africa, and to illustrate through the use of specific examples how a longer term perspective can inform understanding of contemporary environmental problems and issues, such as enhanced soil erosion, forest decline, rangeland degradation, and loss of local knowledge concerning natural resources management (Marchant & Lane, 2014). Several of the sub-projects focused on the ecological, social and economic consequences of the expansion of the ivory trade during the nineteenth century, with particular reference to the northern route through the Pangani Basin and adjacent areas in NE Tanzania (Figure 8.6). Additional research was conducted on the development of specialized pastoralism, and colonial and post-colonial forestry policies and conservation initiatives.

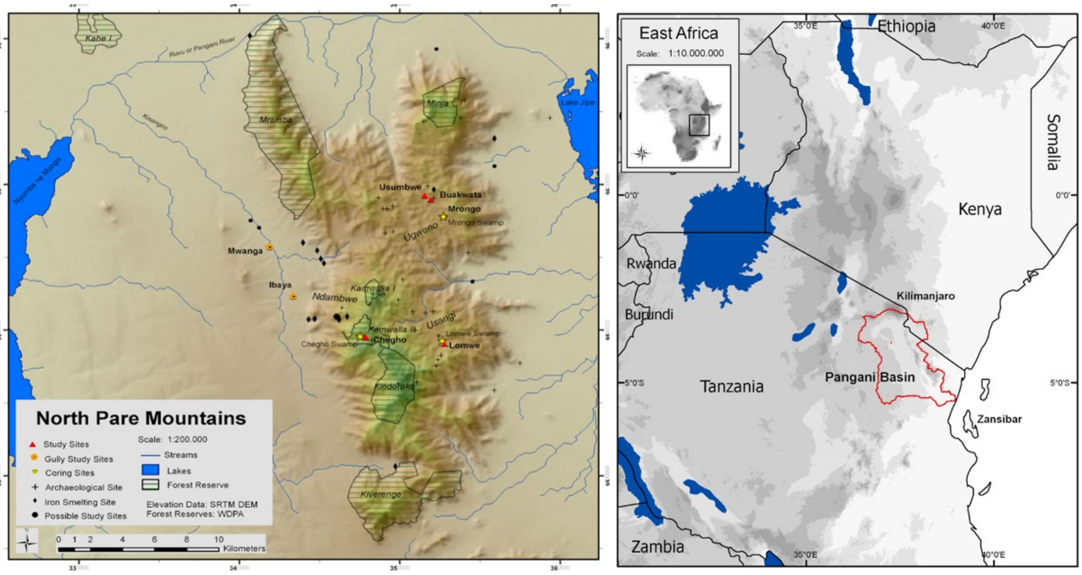


Figure 8.6. Left: General location map of East Africa and the Pangani Basin. Right: Detailed map of the North Pare Mountains showing location of known archaeological sites at the start of the HEEAL project, and geoarchaeological and palaeoecological sampling sites. Sources: Prepared by Matthias Heckmann for the HEEAL project.

The focus on the social and ecological impacts of elephant ivory was chosen partly because elephants are often considered to be ecological architects in their own right, shaping environments through their presence or absence at different trophic levels (Pringle, 2008). Elephant ivory is also known to have been an important export commodity for certain East African societies for upwards of two millennia. It is mentioned, for example, in the first-second century CE mariner's guide known as the Periplus of the Erythrean Sea as a key raw material exported via various early coastal settlements (Casson, 1989). By the early second millennium CE, ivory is mentioned in various Arabic sources as an important trade good on the East African coast, including that by the geographer al-Mas'udi' in the tenth century, who commented "tusks weighing fifty pounds and more" were exported first to Oman and from there on to India and China (Freeman-Grenville, 1962: 15). Several of the ivory workshops around the Mediterranean and in Western Europe during the medieval era also sourced ivory from East Africa (Guérin, 2013), although its flow into Europe was interrupted periodically owing to disruptions to trading networks along the Red Sea. Prior to 1800 CE there was significant demand for East African ivory in India, China and the Middle East, all of which had long-standing trade connections with different ports along the East African Indian Ocean seaboard, from Lamu in the north (Thorbahn, 1979; Ylvisaker, 1982) to Mozambique Island and Sofala in the south (Alpers, 1975), including the regionally important settlements of Kilwa, Mombasa and Malindi. Other traded commodities circulating at the time within the Indian Ocean sphere included gold, ambergris and enslaved individuals (Horton, 2006).

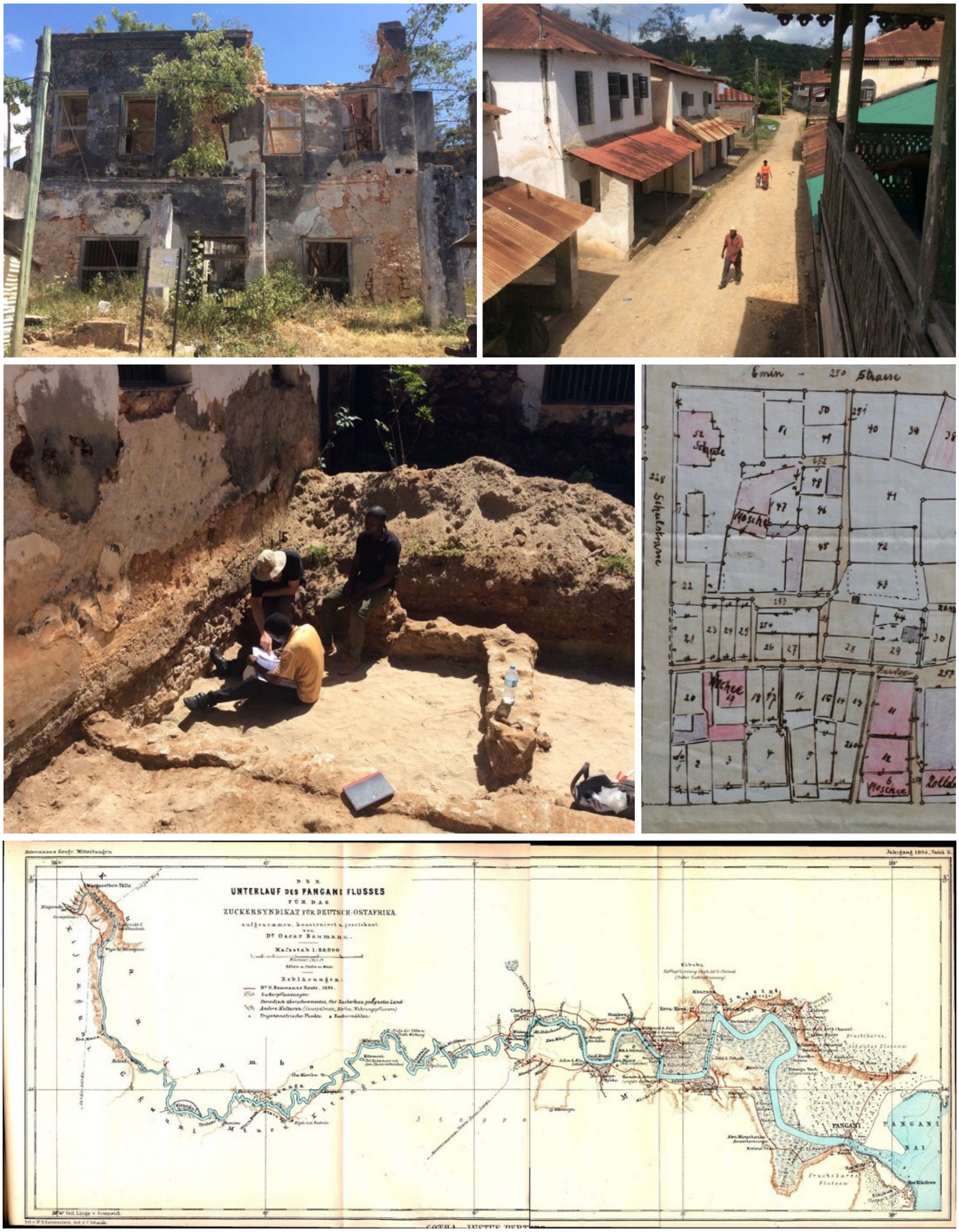


Figure 8.7. Pangani, NE Tanzani: Top left: Remnants of former customs house; Top right: View of India Street; Middle left: Wall footings of buildings adjacent to the German administration building (boma), exposed during excavations in 2019; Middle right: Extract from 1911 German cadastral survey map, 1898; Bottom: Map of lower Pangani River, as compiled by Oscar Baumann in 1895. Sources: Photo: P. Lane; cadastral map Tanzania National Archives GM/167; Lower Pangani map Baumann 1896.

External demand for ivory escalated around the middle of the nineteenth century owing to new demands in North America and Europe (Beachey, 1967). Caravan routes extended westward from several ports on the East African coast as far as Lake Victoria and Lake Tanganyika. At the northern end of the network, these included the town of Pangani (Figure 8.7), which became a key hub for collecting ivory and enslaved individuals, both destined to be transported across the Zanzibar Channel to Zanzibar, which served as the main export hub for both ivory and slaves during the nineteenth century. Customs records and related archives from Zanzibar indicate that the export value of ivory per frasila (c. 15.5 kg) roughly tripled between the late 1820s and early 1870s, and then almost tripled again over the next twenty years (Håkansson 2004). The volume of ivory exported from Zanzibar also rose markedly over this period. For example, total ivory imports into the United Kingdom between 1790 and 1875 rose from around 125 tons to 670 tons, with the sharpest increase occurring after 1840 (Sheriff 1987). Not all of the ivory reaching North America and Europe at this time came from East Africa. Nonetheless, by the mid-19th century, eastern Africa was the greatest supplier, with exports sent to Britain, mainland Europe and the United States of America via two main redistribution centers – Zanzibar and Khartoum. Eastern African ivory was desired over ivory from West Africa partly because it is considered 'softer', making it more suitable for use in the manufacture of piano keys, combs and billiard balls, all increasingly desirable commodities among the burgeoning middle classes in the West (Kelly, 2021).

Additional factors triggered an increased demand in Europe and North America and the geographical shift in the main markets away from Asia. These included technological developments related to the processing and working of ivory, as for example, the invention and patenting of a mechanized system for cutting ivory combs by Phineas Pratt, a goldsmith based in the small hamlet of Deep River on the lower Connecticut River, USA, in 1797 (Malcarne, 2001). From this small invention, new industries emerged and proliferated, encouraging also labor migration, mechanization, and the development of new markets and forms of commodification that had both local and global repercussions (Prestholdt, 2004), as well as having ramifications for local industrial relations Johnston, 1933). The steady expansion of industrial production of ivory piano keys in both Deep River and the nearby hamlet of Saybrook, later renamed Ivoryton, also led to their transformation into 'company towns' (Figure 8.8). In East Africa, there were numerous human agents involved in the extraction, transport, exchange, manufacturing and consumption of ivory during the nineteenth century. These included specialist hunters, middlemen, caravan porters and leaders, customs officials, caravan owners and financiers, ivory buyers, ship captains, warehouse owners, auctioneers, manufacturers, factory workers, shop owners, and consumers, all of whom may have changed aspects of their practices (Rempel, 1998; Håkansson 2007), and may have had differential effects on their immediate environs and the wider landscape, either directly or indirectly.

Whereas the organization of the ivory trade and some of its social, political and economic consequences both in East Africa and more widely have been the subject of historical and anthropological research, other aspects, especially at the landscape scale, had received more limited scrutiny partly because of gaps in the historical and ethnographic sources. A goal of the HEEAL project was thus to try to fill some of these gaps through the integration of a number of complementary research strands aimed at study of the bioarchaeology of the ivory trade; the archaeological record of caravan halts; the archaeology of agricultural intensification; the geoarchaeological record of settlement, farming and iron smelting; the effects of colonial and post-colonial forestry policies; and changing perceptions and representations of East African landscapes. The ultimate objective was to form a more complete understanding of the interaction between human and natural processes and events in shaping East African environments and landscapes than was available from previous research

(Lane, 2010). To accomplish these, the project was structured around a series of sub-projects, each with interlinking components. Each of these are briefly described below, along with their specific outcomes.

Figure 8.8. a) Comstock, Cheney & Co. Upper Mill, Ivoryton, CT; b) Comstock, Cheney & Co. Lower Mill, Ivoryton, CT; c) Sole remaining original piano key bleach house, Deep River Historical Society Museum (The Stone House), Deep River, CT. Photo: P. Lane, 2009.

Bioarchaeology of the Caravan Trade

The aim of this sub-project was to evaluate the use of isotope analysis for determining the geographical origins of individual pieces of elephant ivory. To do this, it was necessary to create a baseline database of isotope values from modern and historic provenanced East African elephants to assess whether multiple isotope analyses are capable of characterizing different habitats and geological signatures within the region (Figure 8.8). These samples were collected from a range of museum collections in East Africa, the UK, Europe and North America (Coutu, 2015). The results showed a separation of the isotope values from provenanced elephants living in distinct vegetation, environmental, and geological zones within East Africa, and all three major elephant extraction zones along the caravan routes (coast, middle, interior) could be differentiated. Having established this, unprovenanced samples from East Africa were tested and the results compared with the baseline data to determine their most likely origin (Coutu, 2012). Although only a small number of unprovenanced samples were tested, the results indicate the viability of using the technique on a larger sample so as to better refine understanding of the spatio-temporal patterning of the trade and its ecological consequences (Coutu et al., 2016). The analysis of the unprovenanced worked ivory also provided insights into the variable uses of ivory in different European and American industries. The study also demonstrated the potential of the technique for understanding long-term trends in elephant ecology which may well be of value for modern conservation efforts (Coutu, 2019).

Figure 8.9. ivory samples from East and West Africa, Ken Hawley Collection Trust, Sheffield (now part of the Kelham Island Museum), June 2009 Photo credit: Ashley Coutu.

Archaeology of the Caravan Trade: Initial fieldwork aimed at relocating former caravan halts, using the few historical maps available as guides to their location, and assessing their state of preservation. Subsequently, excavations were conducted at a sample of sites along the Pangani River (Figure 8.10), supplemented by research in and around the town of Pangani. Aside from mapping surface traces of the nineteenth century caravan trade, emphasis was placed on investigation of possible impacts of the trade on local subsistence strategies and trading patterns, indicated by changes in excavated artefactual and faunal remains. The results indicate, contrary to some historical sources, that several of the settlements pre-date the expansion of the caravan trade (Biginagwa & Ichumbaki, 2018) and that there were no significant changes in herd management strategies or the relative composition of faunal assemblages at any of the investigated sites (Biginagwa, 2012; Biginagwa & Lane, 2021). Beads and muskets represent the only trade goods to have survived archaeologically. The local ceramic industry seems to have been unaffected by the broader socio-political changes that occurred in the region. This and other evidence suggest that the caravan trade may have been less disruptive economically than has been argued previously.

Figure 8.10. Settlement mound at Ngombezi, Korogwe District, Tanzania, associated with the 19th century caravan trade. Left: Mound under how cultivation, prior to excavation, March 2008; Right: Mound undergoing excavation, directed by Tom Biginagwa, July 2008. Photo: Paul Lane.

Archaeology of agricultural intensification: Four seasons of archaeological reconnaissance, survey and test-excavations were undertaken in the Pare Mountains, led primarily by Daryl Stump, but involving all HEEAL team members at different times (Figure 8.11). The focus was on locating archaeological traces of settlement and iron processing activities, mapping the distribution of irrigation furrows, reservoirs, agricultural terraces, and ancient livestock drove ways, and establishing the date, function and cultural affiliations of these through excavation and the recovery of artifactual remains and faunal and environmental samples. The field components comprised the systematic survey and evaluation excavation of an Early to Mid-Iron Age iron smelting site at Kisiwani, coupled with GPS mapping of functioning and abandoned irrigation channels and reservoirs, and associated dry-stone wall terracing, and interviews with local farmers concerning the large area of agricultural terraces around Myamba. The results indicated a steady expansion of agriculture and associated settlement and iron working from c. 1000 CE, with signs of increased iron smithing activity in the highlands from c. 1500-1600 CE (Stump, 2010; Iles et al., 2018). Artificial irrigation reservoirs and areas of agricultural terracing are known from observations by early European explorers to be at least nineteenth century in origin and some could be considerably older in date as suggested by some of the field results. Conversely, the surveys also suggested that the use of dry-stone agricultural terracing was not as extensive in the precolonial period as might be assumed from the accounts of European explorers in the late nineteenth century.

Archaeology and archaeometry of iron smelting and smithing: The Pare Mountains in NE Tanzania are known from both oral and documentary sources to have been a major center of iron production from at least the sixteenth century CE. High-quality magnetite iron ore, derived from the decomposition of iron-mica gneiss, is abundant – typically recovered from black ore sands found along stream beds and erosion gullies. There are also plentiful supplies of clay with refractory properties, making them suitable for making smelting and smithing furnaces and tuyères for attaching to wooden bellows, and the numerous forests and woodlands provided a ready supply of fuel (in the form of charcoal). There was also a market for the iron products, not just across the Pare Mountains, but also in neighboring, densely populated agricultural areas such as Kilimanjaro and the Usambara Mountains. Trade in these items brought economic prosperity and also enabled political power, with certain clans controlling different aspects of iron production (Kimambo, 1969; Håkansson, 2008). The industry was especially vibrant in the mid- to late nineteenth century, when European explorers first visited, noting that iron production was concentrated in just a few areas – around Vudee in South Pare and Usangi and Ugweno in North Pare (Baumann, 1891). While impressed by the scale of activity, some of the observations made by these early European observers seemed to imply that the activity might also be a source of deforestation, with one commenting 'Anything approaching a forest is only to be met with in the uninhabited district in the north-west … Elsewhere everything has been burned down for clearings' (Meyer, 1891: 223). Despite a lack of subsequent detailed research, by the late twentieth century, charcoal production to fuel iron smelting was being linked more explicitly with both deforestation and soil erosion in the Pare Mountains, including in studies focused on land use management in the area, promoting an environmental narrative also invoked (again with limited empirical support) to account for severe soil erosion elsewhere in Tanzania (Lane, 2009; Mapunda, 2013).

Figure 8.11. Left: HEEAL project members discussing stratigraphy and contextual evidence on site during test excavation of an abandoned ndiva (water storage tank), North Pare, March 2008; Middle: Example of excavated abandoned terraces; Right: stone terraces currently in use, 2009. Photo: P. Lane (left), D. Stump (middle and right).

To gather additional data with which to better assess such claims regarding the ecological impacts of iron smelting in the region, and to enhance understanding of the technical elements of both iron smelting and smithing, their spatial distribution and chronology, the HEEAL project undertook foot-surveys and test excavations in North Pare. These efforts focused on the areas where previous archaeological surveys and excavations surveys in the 1960-1970s (Soper, 1967; Odner, 1971), had located evidence of iron production, mostly dated to the second half of the first millennium CE or later. Further lowland and highland smelting sites and a highland smithing site were investigated as part of the EnvIron project, with a range of sites being radiocarbon dated. It was notable that several sites had evidence for large-scale or prolonged activity, in the form of dense slag concentrations, piles of discarded tuyères and preserved furnace remains (Figure 8.12). Smithing remains found at highland sites, were identified by the presence of low-intensity slag tuyère scatters, small slag smithing cakes and hammerscale. Based on the available radiocarbon dates, the lowland smelting sites—on both the eastern and western flanks of the mountains— were established by the early second millennium CE (c. 1000–1250 cal. CE), with production continuing in different locations until the mid-second millennium CE. Highland sites cluster in the second half of the second millennium CE, although the flattened calibration curve for this period makes their precise dating challenging (Iles et al., 2018).

Figure 8.12: a) Upland iron working slag scatter near Mbore, North Pare Mountains, Tanzania; b) Inset of upland slag scatter; c) Close-up of surface scatter. Photo: P. Lane.

The survey and excavation data were supplemented by the results of detailed metallurgical analyses of the recovered slag, furnaces, tuyeres and ore recovered, combining chemical analysis of their major- and trace-element compositions and optical microscopy. Additional information on historical smithing and smelting practices, including the common wood species used for charcoal production, was also gathered through interviews with former and practicing metal smiths. The combined data provided a more detailed understanding of the chronology, distribution, and technological development of iron production in the Pare Mountains than available previously (Iles et al., 2018). A method was also developed for estimating the average quantity of charcoal used per smelt, to provide an estimate of the possible impact of charcoal production on the local woodland resources (Iles, 2019). While several factors, including dating issues, introduce uncertainties to this model (see also, Iles, 2016), on balance, the data suggest that by itself, even at the peak of production activity, charcoal production associated with iron working would not have caused any significant deforestation. The conclusion is also supported by the results of landscape-scale geoarchaeological research (see below), and the palaeoecological research undertaken as part of the KITE project (Finch et al., 2017).

Geoarchaeology of land use and soil erosion history: Three seasons of geoarchaeological reconnaissance, mapping and sampling were undertaken within the framework of the project, focused on a series of basins in the Usangi area of the North Pare Mountains, known to have been historically important loci of human activities. These locations were also targeted because it was anticipated that sediments would be well preserved due to the limited outflow via small, seasonal streams. Soils eroding from the steep hillsides would therefore be retained within the basins and are likely to record erosion and sedimentation histories. The fieldwork entailed survey of forest, basin and eroded soils around Kisiwani, the sampling for palaeoecological remains of localized swamp deposits in the same general area, and the examination and sampling of erosion gullies along the foot slopes derived from streams originating in the highland areas (Heckmann 2011). Emphasis placed was on reconstructing soil catenas [the sequence of different soils occurring along a slope from the crest to the base, that illustrate the sequence of processes of soil formation, deposition and erosion active on the slope over time] across the Pare mountains.

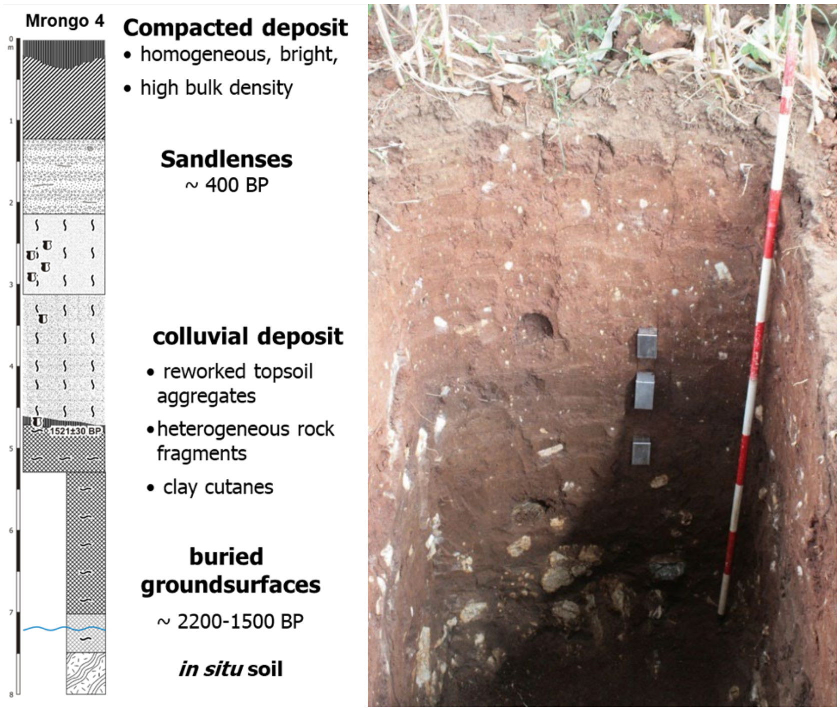


Figure 8.13. Left:Interpretation of depositional history for Mrongo 4 soil test-pit, N. Pare (M. Heckmann, 2011). Right: Example of a soil test-pit with sampling tins. Photo: D. Stump.

Reconstructed soil catenas are key to understanding past human land use and landscape change as they are directly linked to slope processes possibly altered by human activities. Palaeosols exposed in the walls of erosion gullies were also sampled to aid reconstruction of the timing of phases of land surface stability between phases of erosion and sedimentation. Other exposed sections revealed traces of various anthropomorphic remains, including what was probably a sealed pit, as well as buried iron smelting remains and pottery scatters - all indicating that there had been considerable soil erosion further upslope after these features were created. Together with new palaeoecological evidence from swamp cores collected as part of the HEEAL project (Heckmann et al., 2014), and the KITE team's reconstruction of the vegetation history of the Pare Mountains (Finch et al., 2017), it was possible to reconstruct the phases of soil erosion and regional landscape change in the Pare Mountains during the last two millennia (Heckmann 2012, 2014). The results indicated that a distinct phase of soil erosion commenced in North Pare c. 500 CE, and this was likely related to the onset of agricultural land use and associated woodland clearances. More aggressive erosion commenced around 1500 CE, roughly correlating with the archaeological evidence (in the form of terracing and irrigation channels) for agricultural intensification. The study further showed how soil erosion histories can be used in archaeological contexts to understand when and how early human land use starts to shape a landscape and to assess when ecosystem thresholds are crossed leading to land degradation.

Landscape histories, perceptions and policies: Conservation policy can be prone to ignoring or simplifying local environmental values and can operate with, at times, simplified understandings of landscape history based on generalized ideas about population increase, deforestation and soil degradation rather than referencing the results of detailed historical research into actual environmental change. Even if the general trend has been one of agricultural expansion, deforestation and degradation, it is nevertheless important to establish in more detail how and when a particular landscape has changed over time, in order to formulate relevant conservation policies today. To this end, this sub-project aimed to complement the archaeological and geoarchaeological research by HEEAL and related palaeoecological work by the KITE team by providing anthropological insights into the recent history of forest management in the Pare Mountains to explore whether the empirical evidence matched the environmental narratives that were driving policy interventions at the time of the study (von Hellermann, 2016).

Figure 8.14. Sacred forest, Ugweno, North Pare. Photo: P. Lane.

Chome Forest Reserve in the South Pare Mountains was chosen as a useful place to focus research initially because it is the largest forest reserve in the Pare Mountains, where there are several community conservation initiatives. During the early to mid-twentieth century, land use across the Pare Mountains was transformed significantly by successive German and British colonial forest, land, and agricultural directives, often driven by particular environmental narratives of deforestation and land degradation. Moreover, the Leipzig-Lutheran Mission had a station in South Pare, leaving an archive of early twentieth century landscape photographs suitable for reanalysis via repeat photography, which had been digitized by the University of Southern California (von Hellermann, 2020). By collating travel reports, colonial and missionary archival sources and historical landscape photographs, a comprehensive dataset of historical landscape change in north-eastern Tanzania over the last 150 years was compiled. Through the use of historical photographs and ethnographic research into landscape memory, it was also possible to get a better understanding of how and why different groups perceive landscape change differently and so link the project's historical and archaeological insights to current policy concerns, and explore their implications for existing development and conservation initiatives in north-eastern Tanzania. Contrary to narratives that reported continued loss of tree cover throughout the 20th century (e.g. Mbaga-Semgalewe and Folmer, 2000) the repeat photography work showed increased levels of vegetation in the early 21st century when compared to the early 20th (see Figure 8.15), although species composition and hence species diversity are difficult to discern in these images. Additional archival research, supplemented by oral histories and field observations, confirmed that tree cover in South Pare has increased since the mid-twentieth century although overall species diversity has declined (von Hellermann, 2016), with the exception of the sacred forests and groves that scatter the landscape which remain significant biodiversity hotspots (Ylhäisi, 2004; Sheridan, 2009).

Figure 8.15. Left: Pauline von Hellerman and Ashley Coutu matching a historical photograph of the view above Gonja Mission Station with the modern landscape, in 2009. Top right: View of Pare Mountains from Gonja Mission Station, ca 1900–14. (. All rights reserved. Reproduced with permission. Bottom right: Repeat photo of the same view taken in June 2009. Sources: Daryl Stump (left); Photographer unknown, LLMA 5-601. © Evangelisch-Lutherisches Missionswerk Leipzig (top right); Pauline von Hellermann (bottom right).

Summary

The combined research by the HEEAL, Environ and KITE projects hosted at the University of York generated a wealth of data on the changing relations and interactions between humans, their environments and regional climate systems over at least two millennia. The landscape scale approach allowed comparison of the possible effects of different anthropogenic and natural processes, agents and actors, while at the same time helped refine understanding of more localized responses, adaptations and ecological changes. While the archaeological and historical anthropological research in the Pare Mountains generated new substantive evidence that appears to contradict older environmental narratives about these landscapes, it is also evident that the expansion of the caravan trade in the nineteenth century would have had variable impacts and consequences across the wider region cautioning against overgeneralization. As critically, the research also demonstrated that these changes were also enmeshed within a much larger network of processes that linked East Africa with other parts of the globe, especially North America and the United Kingdom, creating entangled histories of early industrialisation, commoditization and mercantile capitalism. Landscape archaeology was key to this study, but so too were a number of other historically oriented disciplines, reinforcing the need to transdisciplinary approaches in historical ecology, more generally (French, 2019).

Another important insight from the project was that reconstructing the history of soil erosion and colluviation helped explain why archaeological surveys undertaken by members of the HEEAL team and previous researchers failed to locate traces of early farming communities in the uplands, despite other indications (both palynological and geoarchaeological) of their presence in the early first millennium CE. In essence, the results show that shifting cultivation with dispersed settlement in this period helped initiate the process of hillside erosion, which ultimately erased traces of the earliest farming settlements in the uplands and buried those on the lower slopes beneath thick deposits of colluvial material. Radiocarbon dates from iron smelting sites in the lowlands further indicate that early farming communities were well-established by c. 1000 CE, with upland erosion continuing at a slow but steady rate for the next five hundred years or so, with some intermittent phases of stability. Between c. 1500-1600 CE, the rates of erosion increased markedly, seemingly corresponding with agricultural intensification and investment in landesque capital (irrigation canals and hillside terracing) and the first signs of iron smithing in the highlands. These smithing sites are both cut into and are sealed by colluvium, so erosion pre- and post-dates them.

All these developments pre-date the intensification of the caravan trade, nd were potentially linked to broader socio-political changes and the emergence of the Pare kingdoms although further research is needed to verify this. It is perhaps also significant that the research on the former caravan halts along the lower Pangani River also showed that these settlements had a much longer history than had been inferred from the sparse documentary sources, and as in the Pare Mountains the data recovered point to an expanding regional economy from c. 1500 CE. It thus seems unlikely that the landscape conditions noted by the earliest European explorers were recent developments, although again more research across a wider sample of terrains and ecological settings is needed to explore this issue. At the very least, the research results from these three linked projects suggest agricultural intensification and economic specialization across the region pre-dates the better documented phase of intensification that has been extensively researched by environmental historians (see, e.g., contributions to Maddox et al., 1996), and that the ecological changes to these landscapes commonly attributed to the impacts of the caravan trade and subsequent imposition of colonial rule, may well have their origins much further back in time.

Conclusions

Archaeological research in its many different forms is a key component in Historical Ecology projects. Archaeology provides important components, including regional analysis of human settlement patterns and transportation networks, chronologies of human settlement patterns over time, important environmental chronologies through the analysis of excavation soils, and more. Archaeologists are accustomed to working in interdisciplinary teams, and are generally open to expanding this context by including the other disciplines described in this volume in order to address Historical Ecology questions. While much archaeological research is at the site level, or concerned with intra-site patterning, and even at microscopic levels, landscape scale research is equally fundamental to contemporary archaeological research. As illustrated here through a detailed case study, the integration of different scales of analysis is also central to developing coherent explanations of environmental transformations, continuities and regime shifts and the relative contributions of anthropogenic and non-anthropogenic factors and agents in the shaping of local and regional ecologies. As numerous examples now demonstrate (see Siegel, 2018; Isendahl and Stump, 2019; Riede and Sheets, 2020; Colonese and Milheira, 2023 for a selection of recent case studies), these deep landscape histories also have much to contribute to addressing current and future socio-ecological challenges.

References

Abueladas, AbdEl-Rahman and Akawwi, Emad 2020. Ground-penetrating radar inspection of subsurface historical structures at the baptism (El-Maghtas) site, Jordan. Geoscientific Instrumentation, Methods and Data Systems, 9(2): 491–497, 2020 (https://gi.copernicus.org/articles/9/491/2020/)

Ashmore, W. 2004. Social archaeologies of landscape. In L. Meskell and R.W. Preucel (Eds.) A Companion to Social Archaeology, Blackwell: Oxford, pp. 255–266.

Aston, M. 1985. Interpreting the Landscape: Landscape Archaeology and Local History. London: Batsford.

Aston, M. and Rowley, T. 1974. Landscape Archaeology: An Introduction to Fieldwork Techniques on Post-Roman Landscapes. Newton Abbot: David and Charles.

Balée, W. 1998. Historical ecology: premises and postulates. In W. Balée (Ed.) Advances in Historical Ecology. 13-29.

Balée, W. 2013. Cultural Forests of the Amazon:A Historical Ecology of People and Their Landscapes. University of Alabama Press.

Bailey, G.N., 1983. Concepts of time in Quaternary prehistory. Annual Review of Anthropology 12: 165–192.

Bailey, G.N. 2007. Time perspectives, palimpsests and the archaeology of time. Journal of Anthropological Archaeology 26: 198-223.

Banning, E.B. 2002. Archaeological Survey. Springer

Barker, P. 1993. Techniques of Archaeological Excavation, 3rd edition. London: Routledge.

Baumann, O. 1891.Usambara und seine Nachbargebiete. Berlin: Dietrich Reimer.

Bayr, U. 2021. Quantifying historical landscape change with repeat photography: an accuracy assessment of geospatial data obtained through monoplotting. International Journal of Geographical Information Science 35(10): 2026-2046.

Beachey, R.W. 1967. The East African ivory trade in the nineteenth century. Journal of African History 8 (2): 269–290.

Bender, B. 1993. Introduction: landscape - meaning and action. In B. Bender (Ed.) Landscape - Politics and Perspectives. Oxford: Berg, pp. 1-17.

Bieke Cattoor, Krista de Jonge, Thomas Coomans 2019. Mapping Landscapes in Transformation: Multidisciplinary Methods for Historical Analysis. Leuven: Leuven University Press.

Biginagwa, T.J. 2012. Historical archaeology of the nineteenth-century caravan trade in northeastern Tanzania: A zooarchaeological perspective. Unpublished PhD dissertation, University of York, UK.

Biginagwa, T.J. 2019. A study of faunal assemblages from 19th century caravan trade halts in north-eastern Tanzania. Studies in the African Past 11: 159-188.

Biginagwa, T.J. and Ichumbaki, E.B. 2018. Settlement history of the islands on the Pangani River, northeastern Tanzania. Azania: Archaeological Research in Africa 53(1): 63-82.

Biginagwa, T.J. and Lane, P.J. 2021. Local animal economies during the nineteenth-century caravan trade along the Lower Pangani, northeastern Tanzania: A zooarchaeological perspective. Azania: Archaeological Research in Africa 56(2): 219-249.

Binford, L.R. 1982. The archaeology of place. Journal of Anthropological Archaeology 1: 5-31.

Branton, N. 2009. Landscape approaches in historical archaeology: The archaeology of places. In D. Gaimster and T. Majewski, T. (eds.) International Handbook of Historical Archaeology, New York: Springer, pp. 51-65.

Bruchac, M. 2014. Indigenous knowledge and traditional knowledge. In Smith, C. (Ed.), Encyclopedia of Global Archaeology. New York: Springer, pp. 3814-3824.

Brück, J. 2005. Experiencing the past? The development of a phenomenological archaeology in British prehistory. Archaeological Dialogues 12(1): 45-72.

Bruno, D. and Thomas, J. (Eds.) 2008. Handbook of Landscape Archaeology. Walnut Creek, CA: Left Coast Press.

Burke, H., M. Morrison, and C. Smith DATE. The Archaeologist's Field Handbook: The essential guide for beginners and professionals in Australia. London: Routledge.

Burke, H., Smith, C. and Zimmerman, L.J. 2009. The Archaeologist's Field Handbook. Walnut Creek, CA: Altamira Press.

Casey, 2008. Place in landscape archaeology: A Western philosophical prelude. In B. David, & J. Thomas (Eds.) Handbook of Landscape Archaeology. Walnut Creek, CA: Left Coast Press, pp. 44-76.

Casson, L. 1989. The Periplus Maris Erythraei: Text with Introduction, Translation, and Commentary. Princeton, NJ: Princeton University Press.

Carver, M.O.H. 2009. Archaeological Investigation. London: Routledge.

Clarke, D.L. 1977. Spatial information in archaeology. In David L. Clarke (ed.) Spatial Archaeology. London: Academic Press, pp. 1-32.

Chapman H 2006. Landscape Archaeology and GIS. Stroud: Tempus.

Chapman, R. and Wylie, A. 2016. Evidential Reasoning in Archaeology. London: Bloomsbury.

Cheetham, P.N. 2008. Noninvasive subsurface mapping techniques, satellite and aerial imagery in landscape archaeology. In B. David, & J. Thomas (Eds.) Handbook of Landscape Archaeology. Walnut Creek, CA: Left Coast Press, pp. 562-582.

Cochran, M.D. and Beaudry, M.C. 2006. Material culture studies and historical archaeology. In The Cambridge Companion to Historical Archaeology, edited by Dan Hicks and Mary C. Beaudry, 191–204. Cambridge University Press, Cambridge.

Colonese, A.C. and Milheira, R.G. (eds.) 2023. Historical Ecology and Landscape Archaeology in Lowland South America. Cham: Springer Nature.

Comer, D.C. and Harrower, M.J. 2013. Mapping Archaeological Landscapes from Space. Springer.

Connolly, J. and Lake, M.W. 2006. Geographical Information Systems in Archaeology. Cambridge: Cambridge University Press.

Coutu, A.N. 2012. Tracing the links between elephants, humans, and landscapes during the nineteenth-century East African ivory trade: A bioarchaeological study. Unpublished PhD dissertation, University of York, UK.

Coutu, A.N. 2015. The elephant in the room: mapping the footsteps of historic elephants with big game hunting collections. World Archaeology, 47(3): 486-503.

Coutu, A.N. 2019. Historic molecules connect the past to modern conservation. In C. Isendahl and D. Stump (eds.) The Oxford Handbook of Historical Ecology and Applied Archaeology. Oxford: Oxford University Press, pp. 208-225.

Coutu, A.N., Lee-Thorp, J., Collins, M.J., & Lane, P.J. 2016. Mapping the elephants of the 19th century East African ivory trade with a multi-isotope approach. PLoS One, 11(10): e0163606.

Crawford, O.G.S. 1953. Archaeology in the Field. London: Phoenix House.

Cronon, W. 1996. The trouble with wilderness: Or, getting back to the wrong nature. Environmental History, 1(1): 7–28.

Crumley, C.L. 1987. Celtic settlement before the conquest: the dialectics of landscape and power. In C.L. Crumley and W.H. Marquardt (eds.) Regional Dynamics: Burgundian Landscapes in Historical Perspective. New York: Academic Press, pp. 403-429.

Crumley, C.L. (ed.) 1994. Historical Ecology: Cultural Knowledge and Changing Landscapes; School of American Research: Santa Fe, NM.

Crumley, C.L. 1995. Heterarchy and the analysis of complex societies. Papers of the American Anthropological Association 6: 1-5.

Crumley, C. L. 2021. Historical ecology: A robust bridge between archaeology and ecology. Sustainability, 13(15), 8210.

Descola, P. 1996. In the Society of Nature: A Native Ecology in Amazonia. Cambridge: Cambridge University Press.

Descola, P. 2014. Beyond nature and culture. In G. Harvey (Ed.) The Handbook of Contemporary Animism. Abingdon: Routledge, pp. 77-91.

Finch, J., Marchant, R. and Courtney Mustaphi, C.J. 2017. Ecosystem change in the South Pare Mountain bloc, Eastern Arc Mountains of Tanzania. The Holocene 27: 796-810.

Foley, R. 1981. A model of regional archaeological structure. Proceedings of the Prehistoric Society 47: 1-17.

Förster, F., Großmann, R., Hinz, M., Iwe, K., Kinkel, H., Larsen, A., Lungershausen, U., Matarese, C., Meurer, P., Nelle, O., Robin, V. and Teichmann, M. 2013. Towards mutual understanding within interdisciplinary palaeoenvironmental research: An exemplary analysis of the term landscape. Quaternary International 312: 4-11.

French, C.A.I. 2019. Grappling with interpreting and testing people-landscape dynamics. In C. Isendahl and D. Stump (eds.) The Oxford Handbook of Historical Ecology and Applied Archaeology. Oxford: Oxford University Press, pp. 263-278.

Gadgil, M., Berkes, F. and Folke, C. 1993. Indigenous knowledge for biodiversity conservation. Ambio, 22(2-3):151-156.

Gater, C.J. 2003. Revealing the Buried Past: Geophysics for Archaeologists. Stroud: Tempus.

Gilbert, M.E., Deriquito, R.C., Lam, S.B. and Roth, S. 2023. Methods for finding the location of historical photographs for repeat photography. Madroño 69(3): 252-262.

Guérin, S.M. 2013. Forgotten routes? Italy, Ifrīqiya and the Trans-Saharan ivory trade. Al-Masaq, 25(1): 70-91.

Haila, Y. 1997. 'Wilderness' and the multiple layers of environmental thought. Environment and History, 3(2): 129-147.

Hastings, J.R. and Turner, R.M. 1965. The Changing Mile: An Ecological Study of Vegetation Change with Time in the Lower Mile of an Arid and Semiarid Region. Tucson, AZ: University of Arizona Press.

Heckmann, M.C., 2011. Soil erosion history and past human land use in the North Pare mountains: A geoarchaeological study of slope deposits in NE Tanzania. Unpublished PhD dissertation, University of York, UK.

Heckmann, M. 2014. Farmers, smelters and caravans: Two thousand years of land use and soil erosion in North Pare, NE Tanzania. Catena 113: 187-201.

Heckmann, M., Muiruri, V., Boom, A. and Marchant, R. 2014. Human–environment interactions in an agricultural landscape: A 1400-yr sediment and pollen record from North Pare, NE Tanzania. Palaeogeography, Palaeoclimatology, Palaeoecology 406: 49-61.

Henderson, N. 1992. Wilderness and the nature conservation ideal: Britain, Canada, and the United States contrasted. Ambio, 21(6): 394-399.

Hester, Thomas R. Harry J Shafer, Kenneth L Feder. Field Methods in Archaeology Seventh Edition

Holdaway, S.J. and Wandsnider, L. (eds.). 2008. Time in Archaeology: Time Perspectivism Revisited. University of Utah Press.

Horton, M. 2006. Port cities and their merchants on the East African coast. In A. Green (Ed.) Cities in the World, 1500–2000. Abingdon: Routledge, pp. 15-29.

Hoskins, W.G. 1955. The Making of the English Landscape. London: Hodder and Stoughton.

Iles, L. 2016. The role of metallurgy in transforming global forests. Journal of Archaeological Method and Theory 23: 219-1241.

Iles, L. 2019. Exploring the impact of iron production on forest and woodland resources: Estimating fuel consumption from slag. STAR: Science & Technology of Archaeological Research 5(2):179-199.

Iles, L., Stump, D., Heckmann, M., Lang, C. and Lane, P.J., 2018. Iron production in North Pare, Tanzania: Archaeometallurgical and geoarchaeological perspectives on landscape change. African Archaeological Review 35: 507-530.

Isendahl, C. and Stump, D. (eds.) 2019. The Oxford Handbook of Historical Ecology and Applied Archaeology. Oxford: Oxford University Press

Ingold, T. 1993 The temporality of the landscape. World Archaeology 25: 152-174.

Ingold, T. 2015. The Life of Lines. Abingdon: Routledge.

Jamieson, E. 2017. Understanding the Archaeology of Landscapes: A Guide to Good Recording Practice. London: Historic England.

Johnson, M.H. 2012. Phenomenological approaches in landscape archaeology. Annual Review of Anthropology 41: 269-284.

Johnston, G.A., 1933. Industrial relations in a New England textile mill: The Pequot Mills of the Naumkeag Steam Cotton Company, Salem, Mass., USA. International Labour Review 27: 471-498.

Kimambo, I. 1969. A Political History of the Pare of Tanzania c.1500–1900. Nairobi: East African Publishing House.

Klett, M. 2011. Repeat photography in landscape research. In E. Margolis and L. Pauwels (eds.) The Sage Handbook of Visual Research Methods, London: Sage, pp.114-130.

Kull, C.A., 2005. Historical landscape repeat photography as a tool for land use change research. Norsk Geografisk Tidsskrift-Norwegian Journal of Geography 59(4): 253-268.

Lane, P.J. 2009. Environmental narratives and the history of soil erosion in Kondoa District, Tanzania: An archaeological perspective. International Journal of African Historical Studies 42: 457-483.

Lane, P.J. 2010. Developing landscape historical ecologies in eastern and southern Africa: opportunities and challenges. African Studies 69: 299-322.

Lindholm, K.J. and Ekblom, A. 2019. A framework for exploring and managing biocultural heritage. Anthropocene 25: 100195.

Lock, G. and Molyneaux, B. L. (eds.) 2006. Confronting Scale in Archaeology. New York: Springer.

Lucas, G. 2012. Understanding the Archaeological Record. Cambridge: Cambridge University Press.

Maddox, G., Giblin, J. and Kimambo, I.N. (eds.) 1996. Custodians of the Land: Ecology & Culture in the History of Tanzania. Oxford: James Currey.

Madry, S. 2007. An Evaluation of Google Earth for Archaeological Exploration and Survey, in: Clark, J.T. and E.M. Hagemeister (eds.) Digital Discovery. Exploring New Frontiers in Human Heritage. CAA2006. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 34th Conference, Fargo, United States, April 2006. Archaeolingua, Budapest, pp. CD-ROM 329-337.

Mapunda, B.B. 2013. Ironworking and deforestation in pre-colonial Africa: The case of Kondoa Irangi, central Tanzania. Utafiti 10(2): 65–89.

Marano, M. 2017. L'idée de paysage entre esthétique et géographie. Journal of Interdisciplinary History of Ideas, 6(12):, 1-34.

Marchant, R. and Lane, P.J. 2014. Past perspectives for the future: foundations for sustainable development in East Africa. Journal of Archaeological Science 51: 12-21.

Maschner, H.D.G. and Chippindale, C. (eds.) 2005. Handbook of Archaeological Methods, Volume 1. Lanham: Altamira Press.

McMillon, B. 1991. The Archaeology Handbook: A Field Manual and Resource Guide. Wiley.

Meagher, M. and Houston, D.B. 1999. Yellowstone and the Biology of Time: Photographs across a Century. Norman, OK: University of Oklahoma Press.

Meyer, H. 1891. Across East African Glaciers: An Account of the First Ascent of Kilimanjaro [translated by E. Calder]. London: George Philip & Son.

Molyneaux, B.L., Carmichael, D.L., and Lafferty III, R.H. 2003. Excavation. Lanham: AltaMira Press.

Monroe, J.C. and Ogundiran, A. (eds.). 2012. Power and landscape in Atlantic West Africa. In J.C. Monroe and A. Ogundiran (eds.) Power and Landscape in Atlantic West Africa: Archaeological Perspectives. Cambridge: Cambridge University Press, pp. 1-46.

Morrison, K.D. and Lycett, M.T. 1994. Centralized power, centralized authority? Ideological claims and archaeological patterns. Asian Perspectives 33: 327-350.

O'Brien, M.J. and Lyman, R.L. 2002. Seriation, Stratigraphy, and Index Fossils: The Backbone of Archaeological Dating. London: Kluwer Academic Publishers.

Prestholdt, J. 2004. On the global repercussions of East African consumerism. The American Historical Review 109(3): 755-781.

Pringle, R.M., 2008. Elephants as architects in East African savannas. Bulletin of the Ecological Society of America 89(1): 20-24.

Rajala, U. and Mills, P. (eds.) 2017. Forms of Dwelling: 20 Years of Taskscapes in Archaeology. Oxford: Oxbow Books.

Rempel, R. 1998. Trade and transformation: participation in the ivory trade in late 19th-century East and central Africa. Canadian Journal of Development Studies/Revue canadienne d'études du développement 19(3): 529-552.

Richards, T. 2008. Survey strategies in landscape archaeology. In B. David, & J. Thomas (Eds.) Handbook of Landscape Archaeology. Walnut Creek, CA: left Coast Press, pp. 551-561.

Riede, F. and Sheets, P. (eds.) 2020. Going Forward by Looking Back: Archaeological Perspectives on Socio-Ecological Crisis, Response, and Collapse. Oxford: Berghahn Books.

Roskams, S. 2001. Excavation. Cambridge: Cambridge University Press.

Schiffer, M.B. 1987. Formation Processes of the Archaeological Record. Albuquerque: University of New Mexico Press.

Scott, S.L., Venter, Z.S., Petersen, H., Jack, S.L., Navarro, R.A. and Hoffman, M.T. 2021. Documenting changing landscapes with rePhotoSA: A repeat photography and citizen science project in southern Africa. Ecological Informatics 64: 101390.

Sheridan, M. 2009. The environmental and social history of African sacred groves: A Tanzanian case study. African Studies Review 52: 73-98.

Siegel, P.E. (ed.) 2018. Island Historical Ecology: Socionatural Landscapes of the Eastern and Southern Caribbean. Oxford: Berghahn Books.

Sinopoli, C.M. and Morrison, K.D. 1995. Dimensions of imperial control: The Vijayanagara Capital. American Anthropologist 97: 83-96.

Spencer-Wood, S.M. 2010. A feminist framework for analyzing powered cultural landscapes in historical archaeology. International Journal of Historical Archaeology 14: 498–526.

Spencer-Wood, S.M. and Baugher, S. (2010). Introduction to the historical archaeology of powered cultural landscapes. International Journal of Historical Archaeology 14: 463-474.

Stump, D. 2010. Ancient and backward or long-lived and sustainable?" The role of the past in debates concerning rural livelihoods and resource conservation in Eastern Africa. World Development 38(9): 1251-1262.

Stump, D. 2013. On applied archaeology, indigenous knowledge, and the usable past. Current Anthropology 54(3): 268-298.

Stump, D. 2019. Digging for indigenous knowledge. In Isendahl, C. and Stump, D. (eds.) The Oxford Handbook of Historical Ecology and Applied Archaeology. Oxford: Oxford University Press, pp. 137-

Tilley, C. 1994. A Phenomenology of Landscape: Places, Paths and Monuments. Oxford: Berg.

Vidal de la Blache, P. 1903. Le tableau de la géographie de la France. Paris: Librairie Hachette & Co.

Von Hellermann, P., 2016. Tree symbolism and conservation in the South Pare Mountains, Tanzania. Conservation and Society 14(4): 368-379.

Von Hellermann, P. 2020. Partial stories: Repeat photography, narratives and environmental change in Tanzania. Visual Anthropology 33(4): 363-391.

Widgren, M. 2004. Can landscapes be read? In H. Palang, H. Sooväli, M. Antrop, & G. Setten (Eds.) European Rural Landscapes: Persistence and Change in a Globalising Environment. Boston, MA: Kluwer Academic, pp. 455–465.

Williams, M. 1983. 'The apple of my eye': Carl Sauer and historical geography. Journal of Historical Geography, 9(1): 1-28.

Witten, A. 2006. Handbook of Geophysics and Archaeology. London: Equinox Publishing Ltd.

Wolverton, S., Figueroa, R.M. and Armstrong, C.G. 202). Integrating historical ecology and environmental justice. Journal of Ethnobiology 43(1): 57-68.

Wylie, A. 2002. Thinking from Things: Essays in the Philosophy of Archaeology. University of California Press.

Ylhäisi, J. 2004. Indigenous forests fragmentation and the significance of ethnic forests for conservation in the North Pare, the Eastern Arc Mountains, Tanzania. Fennia-International Journal of Geography 182(2): 109-132.

CHAPTER 9

MATERIAL CULTURE AND MUSEUM COLLECTIONS

ANAMARIA IUGA, EVA GUSTAVSSON, ALINA-SORINA BIRO

As this Chapter's focus is the relationship between Museum collections and Historical Ecology research, it is best to explain it by focusing on the way museums are organized, what their functions are, and how they can contribute to the Historical Ecology approach. Several examples will accompany our text, from museums from Europe, but mostly from the museums that we, the authors, are, or have been, working for for several years. More detailed examples will present our own activities. These include the activity of the Alexandru Borza Botanical Garden in Cluj-Napoca (Romania) and the way it is involved in reintroducing plants in the wild, in the case they have gone extinct, or are on the verge of doing so. Also interdisciplinary research concerning traditional ecological knowledge and how it was presented to the public by means of exhibitions at the National Museum of the Romanian Peasant (NMRP), in Bucharest Romania. Finally, we present the way a transdisciplinary museum, such as the Lake Vänern Museum of Natural and Cultural Heritage in Sweden works together with local schools to educate the next generation in sustainable development. This is done by introducing the pupils to the rural way of life before electricity and fossil fuels, and the varied landscape with its biodiversity, and how rituals and customs research conducted in traditional communities can help understand the past and the present human-nature relationship.

Museums as a pretext

Museums preserve and present evidence of humankind and the environment (Lewis 2021). More precisely, they safeguard the natural and the cultural heritage identified at different levels: local, regional, national, or worldwide. Museums are primarily depositories of what is considered to be historically valuable. Following the seminal concept coined by Pierre Nora (1998), museums are considered "places of memory" ("lieux de mémoire"), that store the memory of a community and of the environment for their societies. In this role, they have an essential commemorative task (Poulot 2014). At the same time, museums are a method (Thomas 2010) in itself, designed to produce knowledge in a collaborative manner, between specialists, but also with their audience, be they local or wider communities. "It is widely appreciated that museums work when they offer their audiences problems rather than solutions. It might be added that they work best when they allow their audiences to discover things, to be drawn into their unexpected, perhaps disturbing stories" (Thomas 2010: 10).

Although they have already been classified "by the character of their contents, and by the purpose for which they are founded" (Goode 1896: 154), and "[g]iven their diverse origins, varying philosophies, and differing roles in society, museums do not lend themselves to rigid classification" (Lewis 2021). Nonetheless, there are five main types of museums, according to Lewis (2021): (1) general museums; (2) natural history and natural sciences museums; (3) science and technology museums; (4) history museums (including the ethnographical/anthropological museums); and (5) art museums. A sixth type transcends all the others, by nature of its electronic presentation: the virtual museum (see Lewis 2021).

Historical Ecology research can benefit from the information stored in various museums, especially the natural history and natural science museums. Living collections and herbariums, such as the ones found in botanical gardens, play an important role in national and global ex situ conservation, but also in ecological education efforts, thus they are extremely relevant for the Historical Ecology approach.

But other types of museums can be relevant, too. For example, museums of old maps can be equally interesting, as they can store maps from different times that can be used by Historical Ecology researchers, although many historical maps can be found in State Archives or online.

Art museums can also be of interest, as they can present, in the form of art, information relevant for researchers. For example, a retrospective of paintings that depict haystacks can be impressive, as they would show landscape evolution in different times, as depicted by artists. These museums can also be a link between communities and artists, hosting their work in temporary exhibitions and making it accessible for a larger public. Of course, there are artists who are inspired by natural elements and their work is relevant to the historical ecologist, too. A good example is the exhibition "Wildflowers in Romania - a botanical history," hosted by the National Museum of Art in Romania, Bucharest, and organized together with the Romanian Society of Botanical Artists, in between 12 April - 2 June 2019. The exhibition brought together the works of art of Romanian impressionists and fauvism painters, but also the botanic drawings made by a Romanian artist of Italian origin, Angiolina Santocono, who started working for the Botanical Garden in Bucharest in early 1960s, and who composed drawings to depict the botanical characteristics of plants. Another good example is the work of the sculptor Ernö Bartha from Cluj-Napoca, Romania, who is creating sculptures from hay, and whose work was hosted by the Art Museum in Cluj-Napoca in 2004 (the "Arkhai" exhibition), and who has opened since a private park with his works of art, the "Ernö Bartha's Arkhai Sculpture Park" (see also Bartha 2016).

Ethnographic (anthropological) museums are also equally relevant, as there can be found research concerning the human - nature relationship. Of course, at the same time, these types of museums are presenting past traditional ways of living, especially in the countryside, or aspects concerning traditional ecological knowledge. One of the best examples is Skansen Museum (https://skansen.se/en/) in Sweden the first open air museum in the world, dating from 1891, and created by Artur Hazelius. This museum's main goal is to present the way of life in the pre-industrial society of Sweden. Together with the traditional houses and activities presented (using local craftsmen, or employees of the museum that present the specific works), there are also animals present that are typical for the region. Thus the museum is both an ethnographic one, but also a zoo. Hazelius had an idea to preserve everything to do with the old peasant culture (implements, customs, craft knowledge, arts…) that was giving way to the new, modern society. Consequently, he also created the castle like Nordiska museet to display a multitude of items from all over Sweden, but also to host cultural festivities (such as folk dances) in the grand hall. Skansen and Nordiska museet were created simultaneously to work as two complementing entities within the same organization up until 1963, when they were separated (https://www.nordiskamuseet.se/en).

Another good example is the Eco-museums, which are local museums that focus upon a territory and a community. This type of museums developed in France starting with 1971, by a concept developed by Georges Henri Riviere and Hugues de Varine, who stated that an eco-museum:

> "is an instrument conceived, fashioned and operated jointly by a public authority and a local population. It is a mirror in which the local population views itself to discover its own image, in which it seeks an explanation of the territory to which it is attached and of the populations that have preceded it. It is an

expression of man and nature. It places man in his natural environment. It portrays nature in its wildness, but also as adapted by traditional and industrial society in their own image." (Rivière 1985: 182).

Although the Eco-museums, for more than two decades, were very successful in France, and then also abroad (Switzerland, Canada, even Sweden), at the beginning of the 1990s, it was requested in France to remove them from the museum institutions, because they would abuse the local memory (see Poulot 2014), thus very few have kept this title, mostly the ones outside of France.

Museums' purposes and practices

Collect and preserve (safeguard)

The first goal of a museum is to collect and preserve material culture, but also intangible aspects of culture produced over centuries by communities, and, according to the specificity of the museum, to collect (if possible) and preserve natural heritage, too. The collections, which are often heterogeneous, are gathered over time, and are stored in specially designed repositories, with very precise rules concerning the control of humidity, temperature, light, human and other biological factors. Conservation involves both safeguarding of objects stored in collection repositories, treatment, and also restoration (if restoration laboratories and specialists are available). In order to achieve this goal, specialists are hired: museum specialists, in charge of the organization and keeping of the collections, but also restorers, who are in charge of restoring objects.

The objects are divided into various collections, according to age, materiality, geographical country of origin, support, or any relevant criteria concerning the heritage stored. Most museums have an archive, as well, where there are stored documents (some of them concerning the history of the museum), old photos (on various supports), audio recordings (lately on digital support), video recordings (digitally produced in the past decades), and transcription of materials (such as transcriptions of interviews).

The collections are very dynamic: the object number can increase over the years, as any time a new and unique object can be found and can be acquired or can be donated to the museum. For example, the National Museum of the Romanian Peasant (NMRP), in Bucharest was founded in 1990, continuing the museum established in 1906 by Alexandru Tzigara-Samurcaş (1872-1952), who was a Romanian art historian, ethnographer, museum specialist and journalist. He dedicated himself to the creation of The Museum of Ethnography and National Art, which had, as a start, part of the ethnographic objects that were exhibited in the Romanian pavilion at the 1900 International Exhibition in Paris. In 1931 the museum already had 13,800 objects in the collection (Popovăţ 1999: 88). Today, the NMRP hosts more than 90,000 objects, divided into eight different collections: Ceramic; Wood, traditional furniture and iron objects; Traditional clothing; Religious objects; Textiles (with two different categories: indoor textiles, and carpets); Varia (objects related to customs and rituals); Foreign countries (objects that do not originate from Romania); and Samples (for example, textile samples). The collection is growing with every year, as there are either objects that are bought from different communities in Romania, or abroad, and accessed into the museum collections, or there are objects that are received as donations from different persons and benefactors. Thus, one could say that collecting objects in a museum is a dynamic activity. The museum has, also, an archive where there are stored old photos (on various supports: daguerreotypes, glass, paper, and now digital), old documents, old notebooks gathered from villages, recordings (audio, video), transcripts of recordings and so on. This Archive is also increasing in time, with the materials that the researchers of the museums produce, and also with different donations received.

Another interesting aspect in the world of museums is the fact that new types of museums can appear constantly. For example, there is an increasing number of "personal museums" (see Klimaszewski 2018), created by enthusiastic individuals who collect "old" objects from their own community, mainly ethnographic ones, and then display them in their own house. This phenomenon proves that museum practice is already accepted by communities and considered the first option, when preservation of the cultural and natural heritage is at stake. This type of museum could be interesting for historical ecology researchers, as they store local tools that were used, for example, in agriculture, or present the way the local population has capitalized local resources. As an example, in the village of Ieud, Maramureş region (Northern Romania), there is a local museum opened by the Pleş family, where, along with the different objects present in the museum, most of them with interesting stories (see Iuga 2010), the owner decided to present and explain how hemp fabrics were produced before industrialization. They have a corner where they grow hemp (having a special permit from the local authorities that allows them to do so), they soak the hemp stalks in water, crush them with a special tool, transform it into fiber by brushing the crushed stalks with a brush with iron teeth, and, then, spin it into a thread that is used to weave textiles, in the end. Such a demonstration allows historical ecologists to understand the way people were living up to the early 20th century in Ieud, when hemp was still cultivated, for household use.

Document and research

The second goal of a museum is to research and document the collections: studying all possible information about the items, its materiality, description, and history, but also connection to its community of origin, in order to understand the cultural, social, historical and political context that led to its creation (see Pearce 1994). For this type of work, museums employ researchers who document not only the collections, but also go on different fieldwork, according to their specialty.

Natural history museums interested in natural heritage, or botanical gardens, would have among their specialized personnel researchers in plant taxonomy, physiology, ecology, biogeography, ethnobotany, ethnomedicine or historical ecology. Even though in the past three decades the focus in these institutions has been on modern facets of plant science using the latest technologies available in plant genetics (DNA barcoding used in biogeography and taxonomy), in vitro propagation, remote sensing, GIS habitat mapping, etc. there is a newly sparked interest in what not so long ago was considered old fashioned types research. Ethnobotany and ethnomedicine are among those domains, but combined with historical ecology there was a new interest in these subjects. What facilitated this comeback was the need for a new interdisciplinary approach in ecology and conservation science propelled also by technological advancement. The readily availability of online digitized maps, orthophoto maps from free sites like Google Maps, direct contact with social sciences researchers with access to ethnographical archives, all together, make the research process of plant ecologists novel, interactive and full of possibilities.

Ethnographic and anthropology museums, whose main research topic is the material and the intangible cultural heritage, often employ researchers in anthropology, ethnology, or sociology. Among the cultural heritage preserved in such a museum, there are included objects or tools that reveal the way people have been working the land and have shaped the landscape they were settled on. Thus, any type of information that can help document this type of objects is important. At the same time, they can document the intangible heritage of the communities, such as traditional ecological knowledge, which is important to understand the way people are related to the environment (see Berkes et al. 2000; or Iuga et al. 2017). Of course, interdisciplinary research is most productive and beneficial, as one topic of research can be approached from different perspectives. Such an example can be the collaboration between biologists, historical ecologists and ethnologists in studying grassland management (see, for example, Janišová et al. 2021 for a detailed methodology description of such an approach).

Providing services

Museums are constantly involved in the life of the communities where they are located, and each of them have interactive activities (exhibitions, tour guides, creative activities) that have an impact on the public. Thus, a third main goal is to provide different services for the community where they reside, mainly the transfer of knowledge to the public. In this sense, museums are considered to "work" for the interest of the community. Each member of the community, but also outsiders, can learn about the values promoted in the past, and about what is valued in the present. At the same time, museums play an important role in the local economy as they actively contribute to sustainable development of a community, by offering, first of all, jobs for the local specialists, and then, attracting tourists that can spend time in the community, and make use the local lodging and restaurant facilities (see Pereira Roders and van Oers 2011; Jeannotte 2003). Local museums also promote the local cultural heritage and cultural interactive activities, meant for a larger and wider public.

Foremost, museums satisfy the demand of leisure activities, but are, first and foremost, considered to be important educational institutions, as "[m]useums are uniquely powerful semiotic instruments for the creation, maintenance, and dissemination of meanings by fielding together and synthesizing objects, ideas, and beliefs" (Preziosi 2009: 38). These kinds of services are available by means of exhibitions (temporary or permanent ones), educational activities (for children or adults), or other related activities (concerts, conferences, cultural projects, publications of periodicals, handbooks, catalogues, research papers and so on). All these types of activities contribute to providing information to the wide public (Lewis 2021).

One of the activities that has the most impact are the exhibitions. Curators are in charge of organizing exhibitions, to arrange and select all the materials they have available on a topic (e.g.: objects, archive materials, such as old photos, or research materials, interviews, fieldwork recordings of any sorts). For the preparation of an exhibition, the curators work closely with the museum specialists, restorers, but also researchers that have studied on the topic of the exhibition. It is important to mention that during fieldwork, especially because all research can be subject to an exhibition, the researchers must consider asking or developing special techniques, or actions foreseen to help the future exhibition, and that could be visually presented and exhibited. A more detailed example is provided in one of the examples we offer below, the exhibition on hay.

Of great impact are the museum educational activities meant for children, but also for adults. Thus, curators, when thinking of an exhibition, must also work closely with museum education specialists, who, according to the specificity of the theme exposed, can think of several activities they could implement. Such education activities are ruled by the principles of variety and interactivity: "If we want for our visotors to learn something, we must actively involve them in our story" (Aarts et al. 2010: 123). To answer this challenge, NMRP, initiated in 2011, workshops for children that were using the materiality of hay and flowers, in order to create hay-puppets. The children were invited create their own figurine using these raw materials (see Figure 9.1), but only after they were told local legends connected to hay-know-how, that the researchers collected while doing fieldwork. A detailed example of good practice from Sweden, concerning museum education activities for children, will be presented below.

Historical Ecological research, or any interdisciplinary research, can be promoted by means of public conferences,or publications as well. Research activity is defined by promoting itself at academic conferences, but museums offer an arena for a wider promotion, aimed to a more general public. For example, NMRP has a special program of public conferences where there is presented research conducted in the museum, but also conducted by other researchers (mainly anthropologists, but also other social sciences researchers, or natural sciences researchers). In February 2011 there was presented interdisciplinary research on the topic of traditional ecological knowledge and biodiversity of the hay meadows in the Northern part of Romania, and in Sweden, a comparative research conducted by researchers from NMRP and the Swedish Biodiversity Centre (Uppsala University, Sweden). In January 2023 there was presented research on the traveling island of the Danube, conducted by researchers from Francisc Rainer Anthropology Institute of the Romanian Academy of Sciences, the Geography department at the University of Bucharest, and the South-Eastern Europe Studies Institute of the Romanian Academy. This interdisciplinary approach was concerned with the development of the nomadic island, and their meaning for the local communities.

Figure 9.1. Hay figurines created during a creativity workshop at the Romanian Peasant Museum, 2011. Photo: Anamaria Iuga.

Publications edited by museums can be another way to promote interdisciplinary research and historical ecology research. A good example is the Martor Journal, published by NMRP, who has published two thematic issues on topics related to Historical Ecology. These include an issue on the agrarian question (Dorondel and Şerban 2014), and an issue dedicated to hay meadows management (Iuga and Iancu 2016).

Dedicated to providing services for the community, many museums offer facilities for researchers from outside the institution that would like to investigate museum's collections or research data: there are study rooms with special equipment where different objects from the collection repositories can be examined; library access; archive access; meetings with museum specialists (researchers, museum specialists, custodian of collections, curators, restorers, archive specialists).

After presenting the services a museum can provide, we can conclude that museums are "those places where people can experiment captivating things, which can awaken emotions (...) and experience 'aha-moments'" (Aarts et al. 2010: 139).

Illustrations

Botanical gardens. Keepers of historical and applied traditional ecological knowledge

The Alexandru Borza Botanical Garden in Cluj-Napoca (Romania) has had a deep connection with the rural facets of life in Romania even from its early planning and beginnings in 1921. Its founder, professor Alexandru Borza [1887-1971] (Borza 1939), was very interested in the early study of phytosociology, but also in early Romanian ethnobotany, ethnomedicine, rural gardens, and, as a complement, he was an avid researcher of folk traditions and archeology. All of these interests were reflected in the botanical garden he created. For example, among the garden's first ornamental collections was the Dahlia one, a traditional rustic flower cultivated in almost every household during the late 19^{th} - early 20^{th} century, when the majority of Romania's population was living in rural areas.

Figure 9.2. Autumn view of the Transylvanian plain meadow with endemic *Crocus banaticus* and *Colchichum autumnalis* blooming. Photo: Alina Biro.

On a more scientific note, the botanical garden in Cluj has had for a century a whole sector encompassing ⅓ of its size of 14 ha dedicated to discovering the flora and vegetation of Romania, a space where not only different plants are presented to the public, but simulations of natural habitats occurring throughout the country, From the sand dunes of Dobrogea to the continental inland salt steppes of Transylvania, to alpine rockeries of the Carpathians, limestone cliffside forests of Banat and, most importantly, a traditionally managed hay meadow, mown manually twice every year. This sector was a novel concept at the time, as no other garden in the world had this, and it is also important historically, as it came at a time of great celebration for the Romanian people - two years after the Great Unification (1918). Over its prolonged development, the flora and vegetation of Romania also provided insight to horticulturists and botanists alike on how to better grow, conserve and present species to the public. Nowadays, more than ever, this can be an inspiration for ex-situ conservation and repopulation efforts that botanical gardens make all over the world.

The Botanical Garden in Cluj is an example of the longevity of an artificially maintained habitat through the use of traditional ecological knowledge. A major part of the flora and vegetation of Romania is a traditionally managed hay meadow (see Figure 9.2 and 9.3), inspired probably by the founder's young years spent with the locals in his birth village now called Borzeşti (Cluj County). The high biodiversity of grasslands in Transylvania is tody well known in the scientific communities, but the idea to implement it in a botanical garden as a way to conserve and present over 150 grassland species while being cost effective and ecologically sustainable was and still is a revolutionary idea. While this type of "working habitats" was not so common in the past, today more and more botanical gardens use them. This can be seen at Wakehurst Kew Gardens (United Kingdom), where lawn patches have been transformed into meadows full of indicative species including Rhinanthus spp. and meadow orchids, Pannonian dry grassland in East Austria presented by the Botanical Garden of the University of Vienna and rockeries and alpinariums all over Europe (Gothenburg, Grenoble, Kew, Vienna, and so on), or native tropical forest patches like the ones in the Singapore Botanical Garden.

Figure 9.3. Early summer in the Transylvanian plain meadow, on the bottom left acclimatized native daffodils (*Narcissus poeticus*). Photo: Alina Biro.

The Botanical Museum and the Herbarium are extremely important collections that are provided by the Alexandru Borza Botanical Garden to researchers. The garden's Botanical Museum remained in its original form, as designed in 1920s by its creator, professor Borza, and can today even be considered a museum of museums (see Figure 9.4). The 10,000 piece collection has among its displays, botanical illustrates and fossils, a large number of pieces with traditional folk value like different illustrates, wax replicas and vials of conserved traditional fruit, vegetables, grain and fiber plant cultivars which are now extinct from all over Romania. It also contains traditional household objects and clothing made out of these prime materials attesting to the fact that they were once widespread in the rural parts of Romania. By using the museum's collection of traditional cultivars of fruits, grains and handmade objects made of plant fibers and wood, we can have a glimpse of our rural farming past.

Figure 9.4. Left:: General view of an alley in the Botanical Museum. Right: Traditional hat made of tinder fungus (*Fomes fomentarius)* by the moți from the Apuseni Mts. Photo: Alina Biro.

Herbariums have too long surpassed their initial purely taxonomical and chorological role and can now be used to discover and verify traditional land use and practices through the use of habitat indicative plants. Many plant collections have been made over time in all the historical regions of Romania with a special focus on Transylvania and its distinct grasslands which have been studied by early botanists in the region like Johann Christian Gottlob Baumgarten [1765-1843], Florian Porcius [1816-1906], Rezső Soó [1903-1980], and so on. The Cluj Herbarium has more than 800.000 entries, the earliest specimens dating from the 18th century. By examining the old herbarium collections conserved here we can cross reference the change in the flora and vegetation of the areas of interest to us and we can get further insight on what happened when traditional management gradually disappeared and how the vegetation reflected it over time. For example, we can easily discover that the psammophyte flora of Deliblato region, in historical Banat, has changed completely by using specimens collected in regional herbariums from the late 19th century (see Figure 9.5). Endemic elements of the flora there are now almost extinct since the region has been under strict protection from conservationists by instating a grazing ban in the area, as it was previously thought that grazing has only negative effects on this type of flora and ignoring the regions historical transhumance past. As a result, most of the region is now forested with invasive species like black locust (*Robinia pseudoacacia*), planted here initially to stabilize the sands by agronomists and left unchecked by conservation efforts. The only sandy regions that survived are the ones outside the reservation which are still grazed.

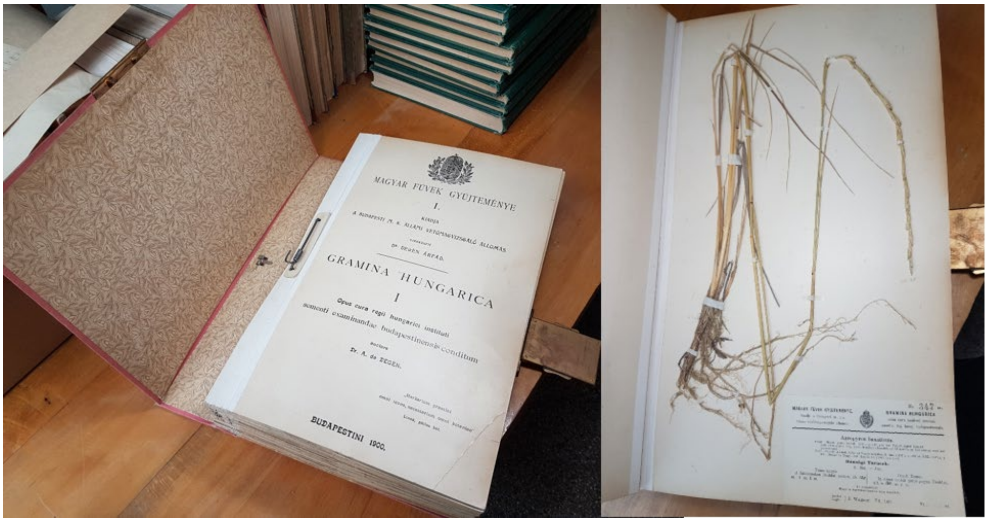


Figure 9.5. Regional herbarium collection dated 1900 by author Dr. Degen von Árpád. On the right the rare grass *Agropyron banaticum* collected from the Deliblato region. Photo: Biro Alina.

Through its Index Seminum (seed index) and newly founded in vitro plant cultivation laboratories and seed bank collection of Carpathian endemic species developed in partnership with Kew's Millennium Seed Bank in Wakehurst (U.K.), the botanical garden in Cluj is able to further expand its conservation efforts. Even though these last two projects are in early development, they can sustain the growing need for new plant material in the garden and for research experiments, while conserving wild populations.

Exhibiting hay

In Romania, semi-natural grasslands are still mostly managed in a traditional manner, as people have animals in their care (cows, sheep, goats, and horses) that need to be provided with winter fodder. During Spring, Summer and Autumn, cattle and sheep are grazing in pastures (common pastures, or private pastures), but the main winter fodder is hay. Romania's rural areas, even if there are many areas where traditional knowledge is well preserved, is a modern society where changes appear, constantly transforming the landscape. One of the main changes is the decrease in the number of animals owned by private households, which leads to the abandonment of hay meadows, and of pastures as well.

Hay is a very practical solution for local animal breeders, as it provides the winter fodder, but it can also become an inspiration for creating art, including the work of the above mentioned artist Ernö Bartha, from Cluj-Napoca, who has created ever since early 2000s, impressive sculptures in hay. He has used hay as raw material for creating his sculptures, transforming a natural product into a cultural one, showing that the raw material of dried grass has artistic values (see Bartha 2016).

Continuing on this idea, hay can become a pretext for understanding or portraying a local culture. For example, the work of the U.S.A. artist photographer Kathleen Laraia McLaughlin, gathered in the album "The Color of Hay" (McLaughlin and McLaughlin 2011), after living for one year (1999-2000) in a remote village in Maramureş (Romania).

In addition to this, hay can be valued by a larger public in exhibitions. For example, in 2015, NMRP hosted the exhibition "The Traditions and Transitions of Hay" (20 July - 16 August 2015), that was focused on hay as a cultural product, and where materiality was exhibited together with the intangible heritage. As explained by Bogdan Iancu, one of the researchers, the exhibition came "after many years of doing field research. The starting point was simply the objects we came across during our fieldwork in rural areas - we'd see scythes with handles made out of bicycles bars hanging from the eaves of the peasant houses where we stayed or did interviews. We'd see plastic rakes instead of traditional wooden ones, rakes whose teeth were replaced because they had been torn or lost… This is how we got the idea that this material universe of objects which generates hay must illustrate somehow the cultural shifts that the hay making process is currently undergoing" (Pănoiu 2016: 173).

Figure 9.6. Opening of the exhibition. In front & back: aerial images. Talking on the microphone is anthropologist Vintilă Mihăilescu, who has been actively supporting the research. On the left side: Bogdan Iancu and Anamaria Iuga, researchers of the Romanian Peasant Museum. Photo: Marius Caraman, 2015.

Presenting the changes that occur in a local rural community for an urban public (material changes, but also those concerning local knowledge and practices) was a challenge the curators and the researchers undertook. The curator, Cosmin Manolache, decided to have a selection of photos, maps, and information that were used in the exhibition. It was crucial to consider the amount of material and to adapt it to the exhibition hall. For this exhibition, the space was very limited, no more than 50 m^2, thus, very few objects were included, just the iconic ones: a scythe, a rake, a pitchfork, and several hay bales (Pănoiu 2016).

The images used told about local traditions and ecological knowledge still to be found in different communities in Transylvania, Romania. The photos focused on landscapes that are iconic for the region, but also on actions of people in the landscape, that are the sources for local knowledge about plants, use of plants, and traditional practices of harvesting hay. The exhibition was telling the story of the new regulations of the European Common Agricultural Policy, as applied in Romania, and how the subsidies influenced the local communities and the way hay meadows are managed. Aerial images that the researchers obtained from the regional agencies (see Figure 9.6) were included. Photographs created during the fieldworks of 2010-2014 were put in dialogue with black-and-white archival images stored in the NMRP's Archive (see Figure 9.7 and 9.8), showing the continuity of practice. Another important source of visual materials used in the exhibition was the work of the American photographer Kathleen Laraia McLaughling, who has been documenting life in the village of Sârbi in the Maramureş region of Romania, where one of the main activities in the summer is the hay harvest. The artist was extremely open to the collaboration and sent us some of her photos that brought to the exhibition an artistic touch (see Figure 9.9).

Figure 9.7. Details of the exhibition photo layout presenting local practices.

Figure 9.8. View of the exhibition's corner presenting local practices and tools used in harvesting hay. Photo: Marius Caraman, 2015.

Figure 9.9. View of Kathleen Laraia McLaughlin's photos. Photo: Marius Caraman, 2015.

Apart from the materials used in the exhibition, whose selection is crucial for the success of the outcome, a special interest must be given to the various levels of collaboration that made possible the endeavor itself. First, there was the collaborative research that took place since 2010, between the researchers from the National Museum of the Romanian Peasant-NMRP in Bucharest (Romania) and from the Swedish Biodiversity Centre (Swedish University of Agricultural sciences). In 2014 it was already clear that in the following year there would be an exhibition organized, thus, during the research of that year, the specialists prepared for it actively, producing special materials. Sounds of the hay meadows were recorded, such as the sound of the grass in the wind, the sound of crickets and other insects, the sound of the ripe "clocotici" (*Rhinanthus*) letting people know that mowing time has started. There were also recordings made with the actions of humans, for example, the sound of a scythe being prepared for the mowing, or a legend told by a local person.

During the research conducted in 2014, some questions were asked considering using the answers for special parts in the exhibition. Such an example was asking the local population to name different plants that were then picked up, dried and exposed, along with other plants. These were then presented like a huge herbarium page in the exhibition (see Figure 9.10).

Some of the materials used in the exhibition are still available online, as a result of another museum effort that allows people to get free access to materials stored in archives and collections. For example, some of the materials that the NMRP is holding in the archives are online (www.arhiva.muzeultaranuluiroman.ro), and some of them are part of the audio materials used in the exhibition about hay. This opens the collections to the public, not only by exhibitions, but also online. It is also an example of the museum working for the public and making information public. In this manner, specialists can reach a wider audience, over a longer time frame, that surpasses the short timing of an exhibition, no matter how long an exhibition may last.

Figure 9.10. In the right side of the photo there are the plants collected and pressed as a herbarium. Photo: Marius Caraman, 2015.

Teaching Swedes about lost habitats and species - "Gifts from the Land"

In contrast to many Romanians, most people in Sweden have never seen a real hay-meadow (i.e. a species rich grassland, managed by cutting, and not "improved" by plowing, fertilization or the sowing of fodder grasses). Late 19th century maps show that meadows were being turned then into arable fields for food and fodder (Gustavsson et al. 2011). Non-improved pastures went the same way or were abandoned or planted with spruce or pine. Many people today react to the lack of insects, but few have the knowledge to connect this to the lack of semi-natural grasslands, or other flowering habitats that historically dominated the landscape. They are not aware of there having ever been any. In 2013, as a response to this, the Lake Vänern Museum of Natural and Cultural Heritage in the rural town of Lidköping in south Sweden, created a new permanent exhibition to show how the clayey plains around the south of Lake Vänern were transformed from a landscape of meadows and pastures for rearing cattle, into a landscape exporting oats to feed the horses in Great Britain, and onwards to the industrialized agricultural landscape of today. The exhibition, named Gifts from the Land, was refurbished in 2020 to better serve the extensive educational activities for school classes, but the idea of giving a voice to the threatened or extinct species is still central. The background material is largely based on the doctoral studies of Eva Gustavsson (2007) concerning land-use change and biological cultural heritage in this area, with added knowledge from fellow curators at the museum concerning the built environment and historical implements.

Figure 9.11: The Gifts from the Land uses a fable concept to reach an audience disconnected from nature, e.g. a spider complaining about relatives moving in from their clear-cut wooded pasture and a cow dreaming of flowers. The exhibition is used in the schools' education on sustainable development. Photo credit: Malena Kindberg.

Different historical landscapes are shown in models and the varied use of the landscape's different habitats are depicted. Modern versions of these landscapes are conspicuously similar. The loss of species and decreases in population sizes is illustrated by giving voice to different animals (Figure 9.11). A cow is dreaming about a legend about a pasture full of flowers, instead of the silage she is served in the barn. The orb-weaving spider *Araneus angulatus* is annoyed with all the relatives moving into his glade, after the neighboring, grazed forest has been planted with spruce. A painting shows animals and flowers in a demonstration against the destruction of their habitats (Figure 9.12). The fable concept was chosen due to the lack of contact that today's children have with nature and its inhabitants. It has been shown that people, not living directly from what nature or low-intense agriculture gives, i.e. in modern societies, have far less species knowledge than people who are dependent on nature for subsistence (Pilgrim et al. 2008). Giving the species human voices is an attempt to help children reconnect to nature.

Figure 9.12. Animals and plants demonstrating against the habitat destruction initiated in the 19th century, which is going on in the background. Painting by museum technician Robert Bernhoft.

The municipality of Lidköping has commissioned the Vänern museum and two other cultural institutions to be part of the school children's education in sustainable development. All children in the municipality go to these institutions in grade 2, 5, and 8 for specially designed programs, in which the Gifts from the Land exhibition is used to illuminate the historical aspects of each theme. The curator and educator Malena Kindberg, who has worked with the renewal of the exhibition and the educational concept, explains: In grade 2, the visit centers around food (Figure 9.12). What did children eat in the 19th century? The children make a timeline with food from the late 19th century until today. What is the same and what is different? How was food preserved before freezers and refrigerators existed? Working with all senses is important for learning, so the children get to taste Swedish turnip, they create characters from vegetables, and they try grinding grain to flour by hand. The children also work with current sustainability issues around food at another exhibition in the museum.

Figure 9.13. Food in the past and in the present is the central theme when the 2nd-grade school children visit the Vänern museum. In 8th grade they work with the production of clothes. Photo credit: Malena Kindberg.

In grade 5, focus is on the landscape and the enormous changes during the last 200 years. The area these children come from is an agro-industrial landscape, where biodiversity is decreasing due to habitat destruction, eutrophication, fragmentation and pesticide poisoning. The program therefore aims at showing them how different every part of the landscape was before the great land transformations. They discuss the difference between old growth forests and spruce plantations by counting species in pictures showing this and talk about the lack of bees in the landscape and why that is. They play a hands-on game (Figure 9.14). Where they have to agree on how to divide the arable fields between them: first according to how it would have been divided between the land-owning villagers before the land transformations. Then they rearrange the arable land according to how a land-surveyor would have done in order to modernize agriculture. In the museum's workshop for creative work, they build insect hotels to bring home.

In the 8th grade, they work with lifestyles and consumption. Historical probates are used to compare what things a person owned some 100 years ago, as opposed to today. Clothes always come into focus. The discussions start around the scarcity of clothes people used to have. It is then directed towards the production systems of fabrics and clothes historically and today (note the flax and the spinning wheel in Figure 9.15. How expensive and labor intensive making clothes is, also today, but that the prices on garments do not cover the real cost of production. How do we treat clothes today compared to in the past, regarding the lifetime of a garment as compared to historically, passing them on to younger siblings, mending, altering, remaking and finally using them as rags? What can we do about this system? Malena Kindberg is often impressed by the ingenuity of the solutions put forward by these young people with their agile minds.

Figure 9.14. Museum curator and educator Malena Kindberg demonstrates how the 5th grade pupils learn how Swedish villages were transformed during the 19th century, by playing a hands-on game. The different colored rods represent arable land, owned by different villagers. Photo: Eva Gustavsson.

In evaluations of the so-called 2,5,8-programme, the teachers are generally satisfied with what and how their pupils learn. The program is designed to cover parts of the compulsory curriculum on sustainable development, which the teachers agree it does. The transdisciplinarity of the Vänern museum enables the inclusion of the less obvious historical and cultural aspects of sustainability into the educational program.

In conclusion, museums, by the way they are organized and how they involve their visitors in an active manner, by interactive exhibitions, or by museum education activities, can provide awareness services to their community, by talking about the past that has contributed to the creation of the landscape, and making them receptive to Historical Ecology issues. With the examples presented above, it is possible to see the way traditional knowledge concerning nature, and natural materiality can reach a variety of audiences: art lovers, knowledge seekers, the general public, children - in other words - all kinds of people.

Rituals and the understanding of local ecological practices

Rituals and customs can explain how a society is organized and the values that it promotes. They are considered to be one of the ways traditional knowledge (including traditional ecological knowledge) is passed down from one generation to another (Bot 2008; Berkes et al. 2000). Through this process, cultural continuity is guaranteed. But rituals have an economic purpose, too, as they can regulate work and the use and distribution of resources. They can, for example, limit and restrict access to critical resources (Scott 1976). Thus, observing rituals that are connected to the agricultural or pastoral practices and understanding their meanings for the community can shed light on the use of local resources and the human-nature relationship, research topics that can be of use for the Historical Ecology approach. After the research conducted by employees of museums, all the data is to be stored in the museum's archive, ready to be consulted by other specialists in the future.

The milk measurement feast, for example, in the rural mountain and hilly areas in Romania is such a custom. Held in Spring, it regulates the way milk (as a product) is divided among the sheep owners (Ivaşcu and Iuga 2022). The custom is performed at the start of the grazing season, in early Spring, on a day that would be different from one community to the other, according to the altitude. It is either after the feast of St. George (23rd of April, as observed in the village of Rogoz, Maramureş region), or in the first half of May (as observed in the villages of Şurdeşti, Maramureş region; or the village of Cămăraşu, Cluj region), but it could be as well in the second half of May, if the village is situated at a higher altitude (as observed in the villages of Botiza and Ieud, Maramureş region). When the milk measurement feast takes place, the summer grazing starts, and the different owners of sheep gather their animals in one flock. After two days of grazing all together, the owners come to the sheepfold, and each one milks their own sheep; the milk is measured, sometimes using an ancient measurement unit, the "font" (which is ½ of a liter), quantities are written down and, according to each local system, it is decided the quantity of the milk, and thus the amount of cheese, the owners would receive during the whole summer grazing season. For example, as observed during research conducted in 2010 and 2013 in Şurdeşti, an owner of sheep would receive thirty-five liters of milk for each half a liter measured on the feast day. After the feast, grazing starts in the pastures situated on the territory of the village, but later in the summer (end of May, beginning of June), the sheep are moved towards the higher altitude pastures. During the grazing period, each owner will come to the summer farm and stay there for a longer period of time, in order to make their own cheese (in the village of Şurdeşti), or take the cheese already made (in the villages of Botiza, Ieud), as much as there is calculated during the Spring feast. When they come, they also bring different food, or other products needed for the shepherds; and this is included in the way they remunerate the shepherd for their work.

The milk measurement feast has an important economical purpose: the division of resources and products. But it also has a critical symbolic reason, as several gestures are performed in order to provide for the protection of the sheep. These gestures make us understand the traditional relationship to nature. For example, a tree is usually cut and placed in the center of the sheepfold. Usually it is a birch - one of the first trees to produce green leaves in Spring; or a fir-tree, an evergreen tree, that is used in other rituals as well in the territory of Romania, all for different purposes, and with various meanings. This tree is called "the cross of the sheepfold," and it is shaped as a cross, either with the branches tied up together (as seen in Rogoz village, 2011), or it is adorned with flowers and ritual bread (Ieud village, see Figure 9.15). In front of the cross of the sheepfold there is placed an ax, in order to protect the sheep from being hit by lightning (Ieud village). The priest is often called to bless the sheep and the shepherd, in order for them to be protected during the summer grazing period.

Figure 9.15. Goats and sheep around the cross of the sheepfold created to protect the summer farm. In the left bottom corner, there is an ax implanted near the cross of the sheepfold. Ieud village, Maramureş region, Romania. Photo: Anamaria Iuga, 2016.

The start of the summer grazing is strongly connected with the rebirth of nature in spring. This explosion of green vegetation is much used in the ritual that is performed when the milk is measured, for the purpose of animal protection. The "cross of the sheepfold" that is implanted in the area of the summer farm is one example. Another is the custom locally called Păpălugără, that is using branches, for the vegetal mask of the Green Man ("Homo Viridis," see Neagota 2019), a usual custom in the village of Cămăraşu (Cluj region, Romania), until 2009, the last year it was performed. The mask had a protective and fertility-providing role. The Green Man leads the sheep flock (see Figure 9.16) from the ingress of the village to the place where the milk measurement is performed. When the sheep were at their final destination, an exuberant water fight followed, the main aim being to soak the Green Man. The purpose of the fight was that by doing this, the sheep will give more milk during the summer.

There is a strong human-nature relationship in a traditional community, as we can see in the above-mentioned examples. Observing and using nature, humans have developed a set of traditional knowledge, but also a set of rules applied by means of rituals, beliefs and actions. These are both practical and symbolic, and thus, following the rules of magic thinking, meant to be both apotropaic (having the power to ward off evil or danger) and to provide for good productivity.

Figure 9.16: The ritual of the Păpălugără (the Green Man), performed before the milk measurement, Cămăraşu (Cluj region, Romania). Photo credit: Anamaria Iuga, 2009.

Limitations

In the work of museums, there are some problems to surpass as well. For example, there is always a question of how much of the data that are stored in museum archives are to be presented to the public and made available to such a variety of audiences, from the general public to specialists. The general trend is to store the data in archives, thinking that perhaps in the future it will be used, but then, the opportunity never presents itself, or when it does, it is, somehow, late, or obsolete. Thus, we strongly believe that data should be made available as soon as possible after research, and the means offered by museums are a very good way to reach a wider audience.

Another issue concerns an administrative aspect, as funding is not always easy to provide, especially funding for research in Historical Ecology, that would be the basis for all other museum activities. Museums are usually subordinate to national, regional, or local public institutions, which provide for its basic funding. Of course, there can exist as well private non-profit institutions, supporting themselves and involving the local communities, mainly for pro-bono work. But when it comes to research, and also to present (in the various ways, as we have seen already) the results of a research, this can be problematic and extra funding should be provided. A solution to this can be offered by accessing funding research opportunities, in collaboration with research institutions. There are, thus, special funding opportunities at an international level, such as various research and development programs supported by the European Union (Horizon, Biodiversa, etc.). Another example is to appeal for private grants or from private donors. For example, in 2018, the Institute of Biology of the Slovak Academy of Sciences was granted a research grant offered by National Geographic for research concerning traditional ecological knowledge in meadow management in the Carpathian Mountains. For the Romanian Carpathians, they have involved an ethnologist from NMRP, who accompanied and conducted research on the way locals are managing grasslands. In this way, research materials were produced, serving the purpose of the research, but, at the same time, to be included in the archives of the museum, and, if the opportunity presents itself, to be used for exhibitions, publications, conferences, or museum education activities.

Conclusions

Historical Ecology research can benefit from museums, perceived as a method per se, (Thomas 2010) but also from museum research and activities, both in the research stage, but also in the way that research information is presented to the public. Museums store material and intangible cultural heritage that is relevant for a local community. They manage, display, and produce knowledge using their collections (Bell 2012). At the same time, museums are relational and engage in a relationship with their audience: they are involved in the life of their communities and develop interactive activities that bear messages to the public (Bell 2012). Such a message can be the interactions between humans and nature, what were the actions that lead to various transformations of the environment, and, at the same time, of society. The different examples that we have presented in the chapter show that experiences among museums can be quite different, but it is a difference that invites creativity, with its unlimited resources. We have seen how museums can be a link between specialists, such as researchers, and the communities, especially the young generation. Museums help transform scientific information into a "serious game," that helps young generations understand the environment, its historical and millennial relationships with all of us.

Museum activities are a solid argument for interdisciplinary research, as all the work done in the museums, from research to exhibitions and museum education activities are the result of good cooperation between specialists in different fields of expertise. Historical Ecology research can gain from this type of interaction, and can, at the same time, get involved in this type of enterprise, having as a common purpose presenting to the public by means of exhibitions, written texts for specialists, and also for a general public, or by means of creativity activities meant for the younger generation.

Bibliography

Aarts, Herman, Anneke van de Kieft, Judikje Kiers, Kees Plaisier, Diana Timmer 2010, Managementul muzeal şi educaţie muzeală în România [Museum Management and Museum Education in Romania]. Amsterdam: Asociaţia muzeelor din Olanda, Reţeaua Naţională a Muzeelor din România.

Bartha, Ernö 2016, "Nature in the City." MARTOR 21: 188-194. [Online at: http://martor.muzeultaranuluiroman.ro/archive/martor-21-2016/bartha_21_2016/]

Bell, Joshua A. 2012, "Museums as Relational Entities: The Politics and Poetics of Heritage." Reviews in Anthropology 41: 70-92. [DOI: 10.1080/00938157.2012.651072]

Berkes, Fikret; Johan Colding and Carl Folke 2000, "Rediscovery of Traditional Ecological Knowledge as Adaptative Management." Ecological Applications 10 (5): 1251-1262.

Borza, Alexandru 1939, Grădina Botanică din Cluj [Botanical Garden from Cluj], Tipografia Naţională S. A. Cluj.

Bot, Nicolae 2008, "Dreptul cutumiar şi folclorul obiceiurilor [Customary law and customs folklore]." In Nicolae Bot, Studii de etnologie [Studies in Ethnology], volume coordinated by Ioana Bot and Ileana Benga, 164-175. Cluj-Napoca: Casa Cărții de știință.

Dorondel, Ştefan, Stelu Şerban (eds.) 2014, Martor 19, "The Agrarian Question – a Historical and Political Economy Outlook." [Online at: https://martor.muzeultaranuluiroman.ro/archive/martor-19-2014/]

Goode, G. Brown 1896, "On the Classification of Museums." Science 3(57): 154–161. [Online at: http://www.jstor.org/stable/1622912]

Gustavsson, Eva 2007, Grassland plant diversity in relation to historical and current land use. Doctoral thesis. Dept. of Ecology, Swedish University of Agricultural Sciences, Uppsala.

Gustavsson, Eva, Anna Dahlström, Marie Emanuelsson, Jörgen Wissman and Tommy Lennartsson 2011, "Combining Historical and Ecological Knowledge to Optimise Biodiversity Conservation in Semi-Natural Grasslands." In The Importance of Biological Interactions in the Study of Biodiversity, ed. Jordi Lopez Pujol, 174-196. Rijeka: InTech. [DOI: 10.5772/24634].

Iuga, Anamaria, Anna Westin, Bogdan Iancu, Monica Stroe, Håkan Tunón 2017, "Rural Communities and Traditional Ecological Knowledge". In C. Crumley, T. Lennartsson, & A. Westin (eds.), Issues and Concepts in Historical Ecology: The Past and Future of Landscapes and Regions, 84-111. Cambridge: Cambridge University Press. [DOI:10.1017/9781108355780.004]

Iuga, Anamaria 2010, "«The Peasant Room» and the Revival of Tradition". Martor 15: 195-204. [Online at: http://martor.muzeultaranuluiroman.ro/wp-content/uploads/2015/07/iuga_site1.pdf].

Iuga, Anamaria, Bogdan Iancu (eds.) 2016, Martor 21, "A Place for Hay. Flexibility and Continuity in Hay-Meadow Management." [Online at: https://martor.muzeultaranuluiroman.ro/archive/martor-21-2016/]

Ivaşcu, Cosmin Marius, Anamaria Iuga 2022, "Contemporary Transformation of the Pastoral System in the Romanian Carpathian. A Case Study from Maramures Region." In Letizia Bindi (ed.), Grazing Communities. Pastoralism on the Move and Biocultural Heritage Frictions, 203-221. New York, Oxford: Berghahn. [DOI: 10.3167/9781800734753]

Janišová Monika, Anamaria Iuga, Cosmin Marius Ivaşcu, Martin Magnes 2021, "Grassland with tradition: sampling across several scientific disciplines." Vegetation Classification and Survey 2: 19-35. [Online at: https://doi.org/10.3897/VCS/2021/60739]

Jeannotte, Sharon M. 2003, "Singing Alone? The Contribution of Cultural Capital to Social Cohesion and Sustainable Communities." The International Journal of Cultural Policy 9 (1): 35-49.

Klimaszewski, Cheryl. 2018. "Towards a Typology of an Emergent Museum Form." Martor 23: 121-140.

Lewis, Geoffrey D. 2021, "museum." Encyclopedia Britannica, 11 Mar. [Online at: https://www.britannica.com/topic/museum-cultural-institution]

McLaughlin, H. Woods, Kathleen Laraia McLaughlin 2011, The Color of Hay: The Peasants of Maramureş. California: Self published.

Neagota, Bogdan 2019, "Homo Viridis contra Strigas: Ethnographic Description and Historical Religious Archeology in Rural Transylvania." Revista de etnografie şi folclor / Journal of Ethnology and Folklore 1-2: 69-93.

Nora, Pierre 1998, „Between Memory and History: Les Lieux de Mémoire." Representations 26: 7-24.

Pănoiu, Anca-Maria 2016, "'Real Hay is the Hay with Local Feedback': Traditions and Transitions of Hay (an interview with Bogdan Iancu, Anamaria Iuga, Cosmin Manolache)." MARTOR 21: 173-180. [Online at: http://martor.muzeultaranuluiroman.ro/archive/martor-21-2016/panoiu_21_2016/]

Pearce, Susan M. (ed.) 1994, Interpreting Objects and Collections. London, New York: Routledge.

Pereira Roders, Ana, and Ron van Oers 2011, „Editorial: bridging cultural heritage and sustainable development." Journal of Cultural Heritage Management and Sustainable Development 1(1): 5-14.

Pilgrim, S.E., Cullen, L.C., Smith, D.J., Pretty, J., 2008. Ecological knowledge is lost in wealthier communities and countries. Environmental science & technology 42, 1004.

Popovăţ, Petre 1999, Muzeul de la Şosea. Martor Journal - Supplement, 4.

Poulot, Dominique 2014, "Intangible Heritage in France. Between Museographical Renewal and 'Project Territory'." Ethnologies 36 (1-2): 177-206. [DOI: 10.7202/1037606ar]

Preziosi, Donald. 2009, "Narrativity and the Museological Myths of Nationality." Museum History Journal 2(1): 37-50.

Rivière, George Henri 1985, "The ecomuseum - an evolutive definition." Museum, special issue "Images of the ecomuseum" 148 (XXXVII, 4): 182-184.

Scott, James C. 1976, The Moral Economy of the Peasant. London: Yale University Press.

Thomas, Nicholas 2010, "The Museum as Method." Museum Anthropology 33 (1): 6-10. [DOI: 10.1111/j.1548-1379.2010.01070.x]

CHAPTER 10

ENGAGED HISTORICAL ECOLOGY

EVA GUSTAVSSON, ELIZABETH JONES

This chapter discusses recent trends that emerge from collaborative interdisciplinary research methods developed in large part by extension and community consultation work. We are motivated by the necessity to advocate for an engaged Historical Ecology that comes from a desire to move beyond theoretical knowledge production to an applied scientific and policy outlet. An engaged Historical Ecology can, and should, be more inclusive of people with traditional ecological knowledge, people of different ages, educational levels, socio-economic status, and other minority/minoritized groups, be they ethnic, racial, religious, or otherwise. This is important, as these constituents often must interact with policymakers, private businesses, public entities or individual property-owners, and they are often in a disadvantaged position. In this sense, an engaged Historical Ecology is an intentional decision to insert historical and ecological understandings into conversations that are often focused only in the present, but actually future-oriented, where certain narratives and experiences from the past are ignored or made invisible in the discussions that stakeholders have when attempting to solve challenges. In essence, this increases the number of participants, and perspectives, multiplies the points of contact that they have with researchers and projects, and provides more seats at the decision-making table.

Disciplinary underpinnings and perspectives

Historical ecology necessarily works on different time levels. When researching fairly recent history, local people are essential sources of knowledge in understanding how the society works (or worked in a recent past) concerning work, leisure, religion, traditions, and more. In traditional societies, these personal stories (chapter 7 and 8) form links to earlier times, e.g. making sense of data and findings in various types of historical records (see section 2). Through the stories about their society, the dynamics in the landscape come to life, formulating new questions and often giving answers to questions not even asked. Local people, who live traditionally off of what the landscape provides, by working in (and with) it, have profound ecological knowledge in the interrelationship between management and the effect that this has on nature. They create "taskscapes" (Ingold, 1993), a socially constructed space of human activity, conceived in space and time. This knowledge is following the rules of cultural transmission (see Baumgardt, 2008): it is handed down through generations and modified through each individual person, family, village etc., according to the current situation in combination with accumulated experience and new developments. Another term for this is Traditional Ecological Knowledge (TEK) (Berkes, 2018).

The instruments researchers use to tap into these complex webs of knowledge are basically the same as in ethnography and oral history. This chapter will not cover these methods and techniques but will instead focus on how to engage the local citizens, which are the stakeholders and carriers of this knowledge. We describe different levels of engagement with the stakeholders, and how researchers, by letting go of absolute authority of the research questions and methodology, can gain deeper insights. We also provide examples from our own and others' research and point to some complications that might arise when scientists get very close to their "objects under study".

Levels of interaction

To really reach into a society, to gain a deeper level of understanding, the researcher needs to let go of some power of the project's content and direction, as well as of leadership, and needs to surrender these to the stakeholders. Depending on the purpose and nature of the project, as well as the type of research questions, different levels of interaction can be used. The characterization is inspired by The Partnership Way (Cashman et al, 2014), which advocates a system called Leading by Convening, where leadership is shared by several people and all stakeholders are encouraged to join in the work. The system was primarily developed in the U.S. to implement new legislation to bring up the education of children with disabilities to a certain level. This was done by inviting a large number of stakeholders from different groups to convene around a difficult topic on which many disagreed. As the projects proceeded, the levels of interaction and engagement deepened into partnerships of authentic engagement. One key phrase throughout the report is "doing the work together". Accepting the fact that not everybody could, or even wanted to, interact on the deepest levels, all stakeholders were welcome to join on their chosen level of interaction. Throughout the projects, individuals would increase or decrease their engagement according to changes in interest or personal possibilities to interact. All input was always welcomed. The report describes four levels of interaction, namely informing, networking, collaborating and transforming, and how a core group of engaged stakeholders, through information, networking and collaboration, can build up an organization with dynamic leadership for transformation of society.

In this chapter we describe how research projects can be run on these four levels, exemplified by our own and others' projects, and we discuss how they fit on one or more levels of interaction.

Informing - telling stakeholders about a project without involving them further.

This is the most basic form of interaction, where you, as a researcher, share or disseminate information with others who care about the issue or locale. The information can be shared at any time in a project; before, during and/or after depending on the purpose of the information.

Informing people before the project begins is a courteous way of drawing land-owners' and other inhabitants' attention to the project that will take place in their area. This is a good way to avoid possible confrontations or misunderstandings, should your purpose of being there be misunderstood. Once, author Gustavsson's field assistant was told off that the neighbors were NOT interested in a windmill behind the house, when in fact she was documenting rare plant species with a GPS. This could possibly have been avoided by posting information, for example, on community notice-boards (this was before social media). Working on other people's properties is comparatively simple in Sweden, with the country's traditional (and now legislated) "right of public access" to areas without buildings or growing crops. But these rights differ vastly between countries, probably entailing time-consuming negotiations between researchers and landowners in many countries. Sometimes access is simply not possible.

Most locals will however be curious as to what is happening in any project concerning their local area. What have the researchers found out so far? What tools are they using? Informing during the project, e.g. halfway through, can have benefits also for the project, as many locals have knowledge that they love to share and which may be of interest. This is where information is bordering on networking. Informing after the project is finished will allow the researchers to share some results as well as to give information on what happens next.

Restricting your interaction to the information level may be necessary, for example due to a restricted budget, as interacting with people takes time. Or perhaps your methods require some distancing. In historical ecology, local knowledge is however hard currency. Informing personally can be accomplished during any local event. It is easier for you to join an already planned event, e.g. to put up an information point at a local fair, than to get people to attend an obscure meeting with an "oddball professor". Make a flier, talk to people. The word will spread.

Local associations are also very good places to start, e.g. local heritage groups. Besides knowing a lot about the area, they often know "everybody" and who would be interesting to talk to. Social media can also be an option. Post basic information about who you are and what you do in a local group. You can then follow up with new posts during and after the project. In smaller communities, the local newspaper will often be more than happy to write about your project. Research budgets can be too tight to fit information into the projects. Some research foundations do however have special calls for outreach purposes, and such a project is used as an example later in this chapter.

There are many complex issues involved here. How do you identify the local/regional/national stakeholders involved? How do you know where they are coming from in regard to the issues you are researching? What is the level of interaction that is appropriate for you regarding interaction and participation with different individuals and groups? What channels of information should be used or avoided? All of these are important things to consider in defining and conducting your work.

Networking – Asking others about their opinions and knowledge, and listening to what they have to say

Networking is the next level of engagement, where the stakeholders are asked to contribute with their knowledge, opinions, and insights which, in turn, may influence the project orientation. This level of interaction is close to classical ethnographic procedures, where the researcher approaches the locals from an outside perspective, asking for information pertaining to the local community, such as the citizens' knowledge about their home landscape, their traditions and insights, i.e. their network of knowledge. Often the topics being studied concern knowledge and traditions that are in danger of disappearing in the near future due to the advanced age of those with this knowledge.

As networking is still a rather limited form of interaction, and there are usually limited resources for it, the timing of network meetings is crucial. The more input you want from the stakeholders, the earlier you need to identify them and consult with them, preferably already while writing the application for funding, but at least as soon as possible after receiving the funding and committing to the project.

Make up a timeline for interaction, to plan what to talk about and how to do this in a logical sequence, is a vital early activity that can guide the way for your research. Plan for who you want to meet and when. Being sensitive to the wishes of the stakeholders as to who wants to meet with you alone or who wants to be in a group is important. In the Swedish example of "Networking" below, one of our interviewees specifically asked to be interviewed together with his friends. This probably made him more comfortable. However, afterwards he was not satisfied with how the management of his own forest had been discussed. A new meeting was scheduled with only him, the project leader and the filmmaker. The filmed material with him, describing how he worked with his forest, was fantastic.

However, this type of knowledge has become increasingly important, from interesting documentations of fading cultures to vital knowledge pieces that fit into the complex jigsaw puzzle of sustainability. In time, it has become obvious that traditional, low-input agriculture or direct, nature-based sustenance, is highly compatible with or, in many cases, a prerequisite for healthy ecosystems. This is expressed in the UN Agenda 2030 Sustainable Development Goals. To reach the deeper levels of traditional knowledge, with higher levels of detail and complexity, deeper levels of interaction should be considered.

It is important to map out a timeline for these interactions: including when to get people involved in project discussions. This is particularly true when there is a pending decision or a near-term potential impact or immediate threat or environmental consequence to a community.

In the next level of engagement, local people are engaged in setting the agenda of what knowledge is important to convey, rather than simply responding to questions.

Collaborating – Engaging people in trying to do something of value and working together around the issue.

Acknowledging, as a researcher, that the experts on traditional knowledge are the people living traditionally, it is a good idea to actually do the research work together with these stakeholders. A lot of the everyday "doing" and "making" in traditional livelihoods give clues and insights into how the system is connected and will give you information you didn't know you needed. For example, heating a baking oven requires another type of firewood than for cooking the daily meal on the stove. This wood needs to be collected and prepared in the correct way, in good time before the baking takes place. Hence, baking influences the use of the forest and probably affects the working schedule of more people than the person doing the baking. This network of knowing what to do, how to do it, and when to do all the things that need to be done in a certain traditional setting, is difficult to research by just doing interviews with questions created from the external knowledge of the researcher. Moreover, all these tasks are obvious to the members of the community and therefore not apparently interesting to convey to a researcher asking about forest management OR baking bread.

Getting stakeholders to engage on this level is complex. The researcher seeks for them to actually do work, to have some influence on the direction of the project, and to be in the methods used, and all of this will need to be transferred to the stakeholders. What historical, cultural, ecological, and traditional questions will engage the stakeholders? What knowledge gaps can the group of collaborators identify? This includes knowledge that the group seeks or perhaps knowledge that the majority society needs to be enlightened about. Is there some sort of threat to a community, a place or a tradition to convene around? This way, Engaged Historical Ecology can also serve a communities' own needs (reviving a defunct or dwindling cultural practice that may need/want the "legitimacy veneer" of external scientific actors). The Partnership Way (Cashman et al, 2014) lifts some issues that need to be processed together on the Collaboration level. These include exploring and acknowledging differences among the participants, developing a common vocabulary, exploring issues to be addressed, and developing grounding documents for the joint work ahead. Another important task is continuing to invite participants to ensure relevant representation. Working together is key.

This intensification in project engagement will naturally lead to more meetings, as well as work between meetings. Researchers and officials (municipal, regional, national) will likely be paid by the project or their respective employers. This is typically not the case for local participants volunteering for the odd interview. However, increased time spent working on the project means more time away from their own livelihood, and perhaps they even need to hire a farmhand to care for the animals. Hence, compensation needs to be considered to create a fair opportunity to participate meaningfully (Tunón, Rytkönen & Bele, 2020).

Transforming – Doing things The Partnership Way (leading by convening, cross-stakeholder engagement, shared leadership, consensus building).

Transformative work is the deepest (or most mature) form of collaborative work, according to The Partnership Way (Cashman et al, 2014). The leadership is flexible and shared by those ready to lead, be it leading the main project or different parts of it. Working towards common goals is the most important aspect, and commitment to consensus is key. Stakeholders are open to disagree as a means to reach agreement. A common vocabulary, developed together, is used. Through consensus, the stakeholders decide on which issues to move forward with, in which order, and by which methods (Cashman et al, 2014). Another concept in The Partnership Way is the relationship of Leader and Learner. On the Transforming level stakeholders acknowledge that they move between the roles of leaders and learners with ease.

Community-based participatory research (CBPR) (Detroit Urban Research Center, 2023; Atalay, 2012) is a related research concept used in health-care, social studies and traditional knowledge, where the aim is not simply to gain new knowledge or insights, for the sake of research, but just as much to enable a path to change for the community. Community can be a geographical delimitation, but also people or groups of people with something in common, which typically puts them at risk for marginalization and/or discrimination. CBPR and The Partnership Way have a lot in common, in that all participants are considered equal partners, to ensure that the right issues are researched and acted upon, to create real change. The stakeholders are perceived as the true experts concerning what needs to be studied and also as carriers of knowledge, whereas the researchers have their academic expertise in the subject and in methodology and analysis. Every step of the research: planning and writing applications, doing the research, analyzing and publishing - is done as a team. Hence, identifying who needs to be at the table to complete the group is essential. Broad participation of academics from different disciplines, fair community representation, and adequate representation from the official society are all equally important and valid perspectives.

The initiative for research may come from a researcher/research team, but also from the community itself, having identified the need for more knowledge in order for the community to improve its situation. If the initiative comes from the researchers, the broad scientific realm (in this case historical ecology) will by necessity be set by the researchers. However, the stakeholders are equally entitled to nominate, discuss, and decide on the subject areas to study. Research methodology may also be subject to discussion but is typically an advanced skill for researchers to choose and perform. If the initiative, on the other hand, comes from the community, the stakeholders will instead seek out the researchers that will best suit their specific questions or problems.

Engaged Historical Ecology is a process and a mindset, by which the researchers must "let go" of their own agendas. Expressly following the needs and desires of the community can be counter-intuitive to any researcher's training, to normative research objectives, and (not least of all) the funding mechanisms that condition most scientific paradigms. However, if we want our work to contribute to a more sustainable framework for the future, then we must transform the mechanisms for conducting research, and how our results are utilized, and by whom.

Ethical dilemmas specifically concerning CBPR have been discussed by Wilson, Kenny & Dickson-Swift (2018), and Tunón, Rytkönen & Bele (2020). One issue concerns proper distancing between researchers and the stakeholders, when it is the stakeholders' traditional knowledge that is being researched. One dilemma may concern research results which are unflattering for the stakeholders. Do you still publish this, even if this may cause conflicts with the group? In historical ecology, research is very often connected to Indigenous peoples or local communities. These societies have good reason to be skeptical towards outside researchers, who have historically treated them purely as research objects, and often with racism and contempt, or at least ignorance

(Wilson, 2008). Will publishing unflattering results stir old animosities? Another issue is the anonymity of the informant, which may likely also be a part of the community research group. Can that person be a co-author? Should they be named or be kept anonymous? How representative are the local participants of the community? Are there e.g. formal or informal hierarchies deciding who will represent the community? To promote respectful conduct, several ethical codes and guidelines have been written, 13 of which have been described and analyzed by Tunón, Kvarnström & Lerner (2016). Wilson (2008) puts forward a paradigm of indigenous research, where the researchers are both indigenous and scholars, which ensures an understanding of indigenous culture.

Researchers who work in a transformative way, point to the novel research ideas, the empowering of the community, and the unexpected insights that this type of collaboration offers. All in spite of the heavy workload it entails, due to the complexity and many people involved (Atalay, 2012).

Examples from our research projects and study areas

Informing - special grants for information project

One research project that author Gustavsson worked on received additional funding to give back information to the citizens and other stakeholders in the local communities. The research had been based on a citizen survey, asking for information on cultural, historical and botanical knowledge about, as well as attachment to, a favorite place. Another part of the project consisted of semi-structured interviews. The ensuing outreach project was therefore partly a way to say "Thank you for sharing". A collaboration was set up with the local Lake Vänern Museum (see Chapter 9), the office of the Biosphere Reserve Lake Vänern Archipelago and Mount Kinnekulle, where the project was located (Figure 10.1), and the municipal offices for culture in the three biosphere municipalities.

Figure 10.1. Map of Scandinavia. Biosphere Reserve Lake Vänern Archipelago and Mount Kinnekulle is enlarged.

The information was published in a booklet (Gustavsson et al, 2019), in a mobile outdoor exhibition (Dahlbom et al, 2020), and in short information films (Anhede et al, 2020). All published material was in Swedish, and in a non-academic language, to make it accessible for most people. The booklet launch was arranged as a workshop for local and regional politicians and officers as an aid to sustainable landscape planning. After the projects (both research and outreach) were finished, the booklet was a popular give-away at biosphere and municipal conferences and workshops, and to extra interested tourists at Tourist Information Points. The exhibition traveled in the municipalities during the summers of 2020 and 2021. Cultural events had been planned for the openings, but sadly, pandemic restrictions stopped most of them (Figure 10.2).

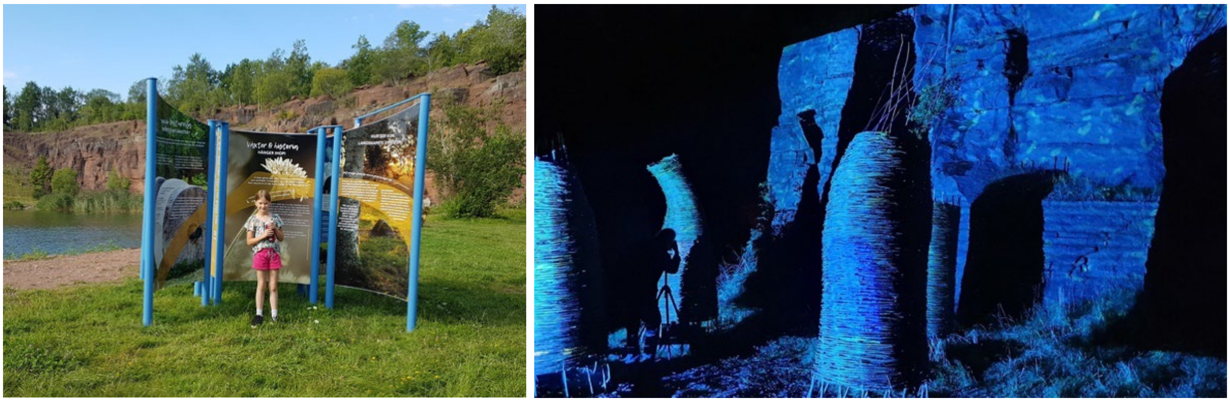


Figure 10.2. Two openings of the same exhibition. To the left, the first opening in 2020, when Covid-19 stopped all cultural events. Photo: Eva Gustavsson. The second in 2021 (right), when a temporary lift in pandemic restrictions allowed for a couple of public cultural events within the information project. Artist Africa Coll's installment of sculptures in front of the flat limestone-quarry wall, where the information film was projected. Information was also conveyed orally and by giving out the booklet. Photo: Anne-Sofie Andersson.

Hence, this is typical for an Information-level project. Before the research project started, the local newspapers published interviews with us, which were followed up with reports from the booklet launch/workshop. The power over the research project was entirely in the hands of the researchers, whereas some power was redirected to the museum and the biosphere reserve office in the outreach project. All input from stakeholders were based on classical "researchers ask, respondents answer" and when both projects were finished, the researchers left with the hope that the project results would be of use.

Networking - Reconstructing historical forestry in southeast Sweden

Forestry in Sweden has, since the late 19th century, focused on increasing yield and efficiency. This has led to monocultural and evenly aged forest plantations succeeding the multi-used forests from earlier times: uses including grazing, selective cutting of firewood and timber, mowing of forest mires, and other traditional forest uses. The historical forests held much higher biodiversity than the modern plantations (Larsson & Danell, 2001), there was timber of higher quality, and they also had more to offer in terms of recreation. We have thus much to learn from traditional forest use (Berkes & Davidson-Hunt, 2006), but is it possible to reach back in time to reconstruct multi-use forests from 60-year-old plantations, when tradition was severed (sensu Rotherham 2008) almost a century ago?

Stensjö was designated a cultural reserve in 2020. It is a hamlet situated in southeast Sweden (Figure 10.3 and 10.4), in a forested area close to where many of Astrid Lindgren's stories were set.

Figure 10.3. Map of Scandinavia. Stensjö is marked with a blue star.

When the hamlet was donated to the Royal Swedish Academy of Letters, History and Antiquities in the 1960's, the houses, fences, fields and pastures were in dire need of restoration. This was paid for by clear-cutting the forests and selling the timber. Following the changes in ideals and conservation philosophies of the last 60 years, and with its reserve status in hand, the Academy and the Kalmar County Administrative Board, as the responsible authority, decided to hence-forward focus on research-based, historically authentic craftsmanship to reconstruct the processes and physical imprints in the village and its entire surrounding landscape, as closely as possible to the late 19th to early 20th century.

Figure 10.4. Stensjö in winter clothing. This hamlet was designated a cultural reserve in 2020, due to its many historical features, along with the ambition to improve authenticity in materials, processes and craftsmanship through research. Photo: Frida Persson.

Stensjö is managed by four employees - a farmer, a forester, a landscape manager, and a gardener. Due to the pandemic and geographic distances, most meetings between the project management, the employees, an Academy representative, and the responsible county officer, were held online. Knowledge gaps pertaining to landscape management were identified by the staff. While the project had its themes, as defined when writing the application, the subject areas and priorities were formulated by the Stensjö people themselves. People holding knowledge of traditional farming and forestry were identified, and methods for conveying desired knowledge were discussed. These knowledge holders had already been involved in the reserve, and so they were part of an already existing network.

Figure 10.5. Typical plantations at Stensjö. Single-aged and evenly spaced Scots pine (Pinus sylvestris L.) on the dry hills and Norway spruce (Picea abies L.) on the moister soils on lower grounds.

One major concern of the reserve is how to transform the single-aged plantations of Norway spruce (*Picea abies L.*) and Scots pine (*Pinus sylvestris L.)* from the 1960's (and onwards) (Figure 10.5) into something resembling the multi-used forests of the late 19th to early 20th century (Figure 10.6). Out of 454 hectares of forest, 264 hectares are to be transformed into many-layered forests for timber and other household needs, and 113 hectares will be converted into semi-open forest for pasture and other uses (Wadstein, 2018). This daunting task needs to be addressed in many ways. The project has offered support in three specific areas: An archival search for historical forest photos, support for the employees to document their own work with a focus on craft skills, and filmed meetings with knowledge holders in different constellations. All three methods are first and foremost directed towards giving input to the employees, but also as ways to pass on the knowledge to others working with historical or other non-clear-cutting forest uses.

Figure 10.6. Grazed, semi-open forest in Stensjö in the late 1920's. Trees are mainly Scots pine. Note the stacked branches of (probably) firewood. Photo: Unknown. From the Erik Stensiö photo collection in The Royal Swedish Academy of Letters, History and Antiquities' archive.

Most resources were allocated to field discussions with knowledge carriers. We decided early on to film the meetings, to explore film as a means to convey landscape management knowledge. The raw material is used both for the memory of the Stensjö staff and for research at the Craft Laboratory into traditional ecological knowledge of historical forest management. After editing, one or two films will be published on YouTube, aimed at forest professionals and other people, interested in or working with historical aspects of forestry.

So who were these knowledge holders? Three elderly men from a parish close to Stensjö, who are very unusual in that they have (to varying degrees) learned local, traditional farming from their parents and older relatives. They have chosen to retain different levels of traditional land use and techniques in their own lives and are also interested in learning more about historical practices and implements. The interviews were most often made by the Stensjö landscape manager. The person behind the camera was chosen on the premises of being proficient both in filming and in landscape management. Being proficient in the craft under study makes that person more apt in directing the camera, seeing what the knowledge holders see, and helping the interviewer in adding questions. The camera person was also responsible for the postproduction, which has proven useful in taking care of the traditional craft knowledge conveyed by the knowledge holders. These men have given us invaluable input on how they work with their own forests (Figure 10.7), what they consider a forest pasture in this part of the country should look like concerning tree-species, and densities of trees and bushes of different sizes. They discussed how Stensjö could transform, improve and manage different parts of the forest pasture to-be, for example concerning a historically mowed forest fen (Figure 10.8). They also discussed how to shape bushes and trees to improve the ground vegetation, to provide shelter and scratching places for the animals, and to create material for traditional wooden fences. In short - providing the feedback Stensjö needed.

Figure 10.7. A filmed interview with one of our knowledge holders and author Gustavsson about his grazed home forest, its historical use and current management, how he plans what needs to be done etc. Screenshot from film: Freja Frölander.

Figure 10.8. Stensjö landscape manager asks advice on how to restore a forest fen meadow and its surrounding. Our three knowledge holders discuss treeless spaces for drying grass, a barn for storing hay, possible historic fencing to keep grazing animals out etc. Screenshot from film: Freja Frölander.

The level of interaction in this project falls into the category of networking. During the application, an already existing, nationwide network of landscape managers and county officers was engaged to identify knowledge gaps to address in the project. Priorities were made by the project group when finalizing the application for funding, and later, in the execution of the project. In Stensjö, the people responsible for planning and executing the management were able to choose among the themes, but not add new themes. Allocation of resources for each project activity was decided by the project group. The knowledge holders were part of an already existing network, built up to support Stensjö with traditional knowledge. One downside was its gender bias, which could have been redeemed, had there been resources allocated for it. Landscape management in general has come to include mainly the male work spheres of the traditional farm work, such as forestry, fencing, scything and pollarding. This does not mean that women did not have their own knowledge on the subjects under study. For example, the care of the animals (except for the horses) was historically a female responsibility, including herding.

In this project, the stakeholders had the most "power" in the initial step, before the application for funding. In later stages, the stakeholders were invited to choose within pre-decided themes and methods, and to point out knowledge carriers. Although the project group kept an open mind for alternatives, the decisions were still made by them.

Limitations and benefits of working with these data. What we can do well and what we cannot

These types of projects typically address one geographical area, specific tradition or cultural sphere at a time. It is paramount to be cautious on making generalizations extending beyond the project's limitations. In countries, like Sweden, where old traditions are all but lost, it is easily done to apply traditional knowledge studied in one area, to other parts of the country, without reflecting on whether this was at all relevant outside the studied area or cultural sphere. Applying historical practices in the wrong context or place, can in the worst cases eradicate local traces of other traditions. However, (re)discovering local traditions in one place, puts us on alert to find similar traditions elsewhere, thereby facilitating new rediscoverings as well as comparisons between different cultures (Sharifian et al 2023).

Another limitation is time, and the changes in societal context that the knowledge holder has experienced. A person's memory and knowledge is not static. Memories change and they may disappear, partly or completely. Craft knowledge will also change through life as new techniques mix with the old. We must also remember that society had already undergone a lot of change when the oldest members of our society were born, hence some traditions had likely already lost at least part of their context when they were young. Therefore, we cannot expect more than fragments of old traditions from any one person. But fragments from a variety of people put together can give us some sort of understandable picture.

One definite benefit of engaged historical ecology, is that traditional knowledge or craft skills or other such types of knowledge do not exist in historical archives. Things like the decision-making on when to perform a certain task on a farm, has never been recorded by any authority, but is highly relevant in current landscape management. Information from knowledge holders may offer new explanations to phenomena found e.g. on historical maps, or odd place names. In other words, knowledge holders are invaluable sources of information.

Best practices and sources of errors and problems. Problems with these data, apples and oranges

Problems with collecting and analyzing data concerning traditional knowledge and practices do most often pertain to the researchers not actually understanding the information given them, due to cultural or linguistic misunderstandings. The farther away from each other in culture and/or language, the greater the risk. Indigenous cultures, in particular, have been subjected to ignorance, prejudice and sometimes outright racism and may therefore rightly be hesitant towards non-indigenous researchers. Therefore it is of great importance to encourage deep levels of engagement from the stakeholders, as well as a readiness from the researchers, to let go of complete control (Wilson et al 2018, Atalay 2012, Wilson 2008).

Cost and effort required, training needed, data size and complexity issues and software or equipment required

Working with people is complicated and time consuming and rarely a smooth ride. A key skill is knowing how to treat people with respect and genuine interest, which may best be trained together with researchers who are already experienced in this type of project and/or already know the people you want to work with. Trust takes time to build. However, the deeper the engagement of the stakeholders, the more interesting, but complicated data. Each person has their own relationship to and knowledge about the subject, which demands more stakeholders to be involved to reach some level of generalization. Analyzing the data demands skills in handling large and complex qualitative data sets, parallel to the statistical skills for quantitative sets.

Archiving data, physical and digital

Personal data must be handled with the deepest respect for personal integrity. Legislation on how to collect and store such data, as well as permissions to publish data, photographs, films etc varies between countries, so it needs to be checked beforehand. Within the EU, the GDPR regulation (European Commission 2023) is a legislation in common for all member states, on how these issues should be handled. It regulates e.g. the rights of the citizens to control if and what of their personal data a register may hold, and whether or not a person wants their photograph published or not. Publishing a photograph with identifiable faces demands the expressed permission of each identifiable person (professional news publications have exceptions). In research projects, guidelines for and storage of such permissions and other personal and/or sensitive data are usually provided by the university hosting the project. Digital archiving is covered in chapter 15.

Existing guidebooks, field guides, and tutorials

The Detroit Urban Research Center homepage provides a comprehensive description of how they have worked with Community Based Participatory Research (CBPR) during the last 25 years for equitable health (Detroit Urban Research Center 2023). They also provide an online course.

Research about indigenous cultures has a history of being colonially tinged, but there is interesting modern research engaging the community, not least when performed by indigenous researchers. Sonya Atalays (2012) Community-Based Archaeology: Research with, by, and for Indigenous and Local Communities and Shawn Wilsons (2008) Research Is Ceremony. Indigenous Research Methods are two examples of the importance of bringing inside understanding of the researched culture, to actually understand the results.

Conclusions

Engaging stakeholders in historical ecological research is very rewarding, be it on a basic information level or a higher, transformational level. On any one level, you will gain a deeper and/or broader understanding as to how the local agriculture, regional trade routes, religious ceremonies, local superstitions and what not, shaped the society, the landscape, the ecological processes etc. The traditional knowledge shared, can work as something like a matrix between the fragments of information from historical and biological records, material culture and place names. Working with people demands skills in networking, planning, negotiation, showing respect and genuine interest, as well as treating people and their shared knowledge in accordance with ethical laws and guidelines.

References

Anhede, J., Guldbrand, S., Eliasson, I., Gustavsson, E., Fredholm, S. & Knez, I. (2020) Film - Min Plats i Biosfären! Produced by the Biosphere Reserve Lake Vänern Archipelago and Mount Kinnekulle in cooperation with the University of Gothenburg, Gävle University and the Lake Vänern museum. https://youtu.be/oVDAxYpNbTg [retrieved 23-05-2023]

Atalay, S. (2012). Community-Based Archaeology: Research with, by, and for Indigenous and Local Communities. University of California Press, Berkeley and Los Angeles, California, USA.

Baumgardt, U. (2008). "Variabilité, transmission, création." In Baumgardt, U., Derive, J. (eds.), Littératures orales africaines : Perspectives théoriques et méthodologiques, 77-101. Paris: Editions Karthala.

Berkes, F. (2018). Sacred Ecology. 4th edition. Routledge, Florence USA.

Berkes, F. & Davidson-Hunt, I. J. (2006). Biodiversity, traditional management systems, and cultural landscapes: examples from the boreal forest of Canada. International Social Science Journal 51:187(35-47).

Cashman, J., Linehan, P., Purcell, L., Rosser, M., Schultz, S., & Skalski, S. (2014). Leading by convening: A blueprint for authentic engagement. Alexandria, VA: National Association of State Directors of Special Education.

Dahlbom, T., Gustavsson, E., Eliasson, I., Fredholm, S. & Knez, I. (2020). Traveling exhibition - Min Plats i Biosfären. Produced by the Lake Vänern Museum in cooperation with the University of Gothenburg, Gävle University and the Biosphere Reserve Lake Vänern Archipelago and Mount Kinnekulle.

Detroit Urban Research Center. (2023). What is CBPR? | Detroit Urban Research Center [retrieved May 30th 2023]

European Commission. (2023). Data protection. Rules for the protection of personal data inside and outside the EU. https://commission.europa.eu/law/law-topic/data-protection_en [retrieved May 30th 2023]

Gustavsson, E., Eliasson, I., Fredholm, S., Knez, I., Nilsson, L.G. & Gustavsson, M. (2019). Booklet - Min plats i biosfären. Department of Conservation, University of Gothenburg.

https://gupea.ub.gu.se/handle/2077/62574

Ingold, T. (1993). "The Temporality of the Landscape." World Archeology 25 (2): 152-174.

Larsson, S. & Danell, K. (2001). Science and the Management of Boreal Forest Biodiversity. Scandinavian Journal of Forest Research 16(suppl. 3):5-9

Rotherham, I.D. (2008). The Importance of Cultural Severance in Landscape Ecology Research. In: Dupont, A. & Jacobs, H. (eds.) Landscape Ecology Research Trends, Nova Science Publishers, ch. 4: 71-87.

Sharifian, A., Gantuya, B., Wario, H.T., Kotowski, M.A., Barani, H., Manzano, P., Krätli, S., Babai, D., Biró, M., Sáfián, L., Erdenetsogt, J., Qabel, Q.M. & Molnár, Z. Global principles in local traditional knowledge: A review of forage plant-livestock-herder interactions. Journal of Environmental Management 328 (2023) 116966.

DOI: https://doi.org/10.1016/j.jenvman.2022.116966

Tunón, H., Kvarnström, M. & Lerner, H. (2016). Ethical codes of conduct for research related to Indigenous peoples and local communities – core principles, challenges and opportunities. In: Drugge A-L. (ed.). Ethics in Indigenous Research. Past Experiences - Future Challenges. Vaartoe - Centre for Sami Research. Umeå, Sapmí and Sweden. ISBN: 978-91-7601-457-8. ISSN: 1651-5153, Sámi Dutkan no. 7

Tunón, H., Rytkönen, P. & Bele, B. (2020). Are there lessons to be learnt? A comparative study of ethical challenges between community-based participatory research and case studies in Sweden and Norway. In: Gallardo Fernandez, G.L., Saunders, F. & Sokolova, T. (eds.) Co-creating Actionable Science: Reflections from the Global North and South. Cambridge Scholars Publishing. Newcastle upon Tyne, UK.

Wadstein, M. (2018). Stensjö by. Beskrivning av skogen, övergripande mål och skötselinriktning. Skogsstyrelsen. https://www.vitterhetsakademien.se/download/18.5d3536b6174bf0dceb64adf/1601209415591/wadstein_2018_stensjo_by_beskrivning_av_skogen.pdf [Forest management plan. Retrieved July 4th, 2023]

Wilson, E., Kenny, A. & Dickson-Swift, V. (2018). Ethical Challenges in Community-Based Participatory Research: A Scoping Review. Qualitative Health Research Vol. 28(2) 189-199. DOI: 10.1177/1049732317690721

Wilson, Shawn. (2008). Research Is Ceremony. Indigenous Research Methods. Fernwood Publishing. Halifax & Winnipeg

SECTION 4

TECHNIQUES AND TOOLKITS

This section presents several of the technologies that can be used in Historical Ecology research projects. It contains five reasonably detailed but entry-level descriptions of some of the most commonly used geospatial capabilities today. These are, in order, Geographic Information Systems (GIS), also referred to as Geomatics, aerial photography and photogrammetry, satellite remote sensing and digital image processing, and satellite Positioning, Navigation, and Timing (PNT), such as the Global Positioning System or GPS. All of these are interwoven and are often used together in varying degrees. We also present the emerging concept of Digital Archiving, and present a look at where all this is going and how the rapid development of these interwoven technologies and toolkits will rapidly change how we conduct our work in the future.

The descriptions in each chapter are presented in a basic manner, so that an informed lay person can understand what the technology is, how it works, and how it can be used in our types of research. We present, as in previous chapters, case studies from our own work to illustrate these capabilities and data, and how they fit into a larger research program. In all cases, we have focused on Open Source tools, so that the maximum number of readers can benefit from these. There are certainly other toolkits that could have been included, such as ground-penetrating RADAR and related geophysical systems, for example, and perhaps we will add these to future editions. We hope that you will find these both interesting and useful, and will consider how you can begin to put these powerful capabilities to work in your own research.

CHAPTER 11

GEOGRAPHIC INFORMATION SYSTEMS AND GEOMATICS

SCOTT MADRY

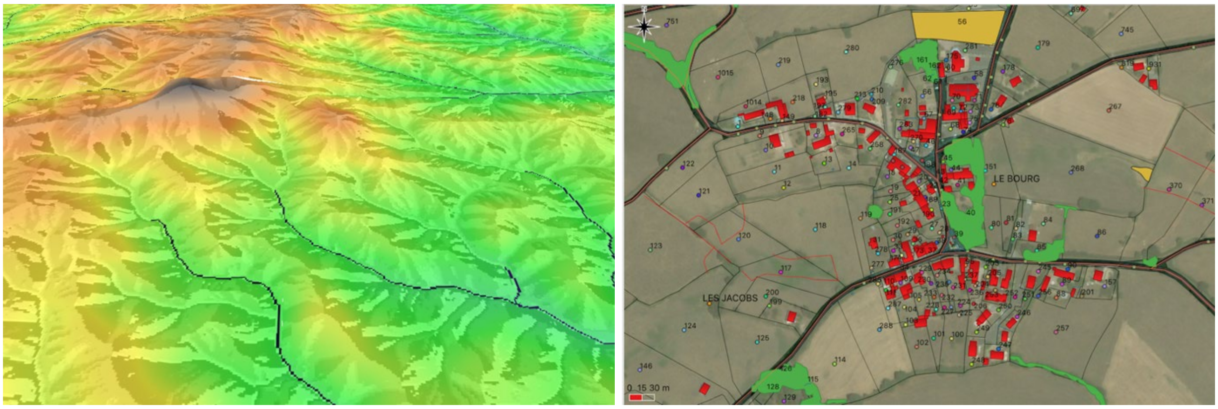


Figure 11.1 Uxeau, France. A Digital Elevation Model (DEM) 3-D view at left, showing the terrain and hydrology network, and at right showing 2011 IGN detailed GIS data, including structures (red) roads (brown), forests (green), the communal cemetery (tan), and individual property parcel lines and parcel numbers. All overlaid over a detailed, high resolution satellite image. Data courtesy IGN, images by Scott Madry of our project QGIS database.

This chapter will introduce the methods, techniques, and approaches of the analysis of spatial data using Geographic Information Systems (GIS), also referred to as Geomatics, in support of Historical Ecology research. GIS can be an integrative supporting technology that enables the combination of multiple types and sources of data into a single digital environment that allows the overlay and analysis of these data. Historical maps, aerial photos and satellite imagery, field survey data, ecological and geological data, human population, demographic, and economic data and more can be combined in a project GIS database and analyzed. GIS involves several steps and techniques, which will be presented, as well as the many sources for such data. The various data can be digitized and fully integrated into a GIS database for further analysis and comparison with other data and the testing of hypotheses. Statistical analysis can be conducted and graphics produced for papers and reports. Powerful Open Source tools, available without cost, are now available that can be shared across project participants, the public, and governments. The chapter will present some examples from our own work, including our long-term GIS research in Burgundy, France.

Disciplinary underpinnings and perspectives

GIS and geomatics are very interdisciplinary activities, with foundations in a variety of disciplines. These include, but are not limited to: geography, cartography, photogrammetry and remote sensing, geodesy, computer science, statistical science, and the environmental sciences. It is also a relatively recent development, with the first systems being developed in the 1970's and 1980's. These disciplines all share similar traditions, in their geomatics sense, of team projects, practical methods, and field investigations as well as lab analysis. Today, geography departments are often the home of much GIS-specific teaching, development, and research in the academic setting, but GIS activities are found, literally, from Archaeology to Zoology and everywhere in between. One of the great strengths is the generic nature of applications, and this fosters interdisciplinary research and investigations such as Historical Ecology projects. Although one can certainly conduct geomatics work individually, it is often seen in the team or group project context, often with a skilled GIS specialist supporting the various disciplinary researchers in integrating their data into the project GIS and assisting with the analysis of the results and the presentation of final graphics and map products.

The Basics of GIS

GIS is a computer-based technology that allows us to store, manipulate, analyze, and present spatial and non-spatial data from many different sources. A GIS is a very powerful and useful computer technology that is also very generic in nature. It has an existing disciplinary user base in archaeology, cultural resource management, and historical regional analysis, as well as for general environmental planning, urban planning, natural resource management, forestry, and agriculture. Each of these is of interest to us in Historical Ecology research, and GIS can be the 'glue' that binds all of these disciplinary investigations together. Spatial data in our GIS database can be used for many purposes and applications across disciplines. GIS is also very scale independent, in that it can be used, with appropriate data, literally from a global or national context down to a very local scale, for an individual farm, for example. It can, if properly used, provide better information for decision making, and can be applied in any situation requiring spatial analysis of the environment or human interaction with the environment. Historical GIS, or HGIS, is a rapidly evolving subfield, where the technology is used for historical and temporal projects such as those of interest here, and there is a growing body of work reflecting this HGIS application (Knowles 2002, Rumsey and Williams 2002).

GIS has many definitions, including "A computer-based system used to capture, store, edit, display, and analyze geographically referenced data at any scale". My favorite definition is by geographer Ron Abler from way back in 1988, when he said that "GIS is simultaneously the telescope, the microscope, the computer, and the Xerox machine of regional analysis and the synthesis of spatial data." (Abler 1988).

GIS is a process as well as data. There are users that want information, and this can be a government agency, a consultant's customer, or an academic team asking various integrated questions. The GIS analyst takes that request for information, and turns this into a process, locating and using the needed data and processing tools to generate and present the desired results. We collect the data and do the analysis and then prepare the requested outputs. This could be in the form of color maps, PowerPoint and web graphics, area and distance measurements, visualizations, or statistical analysis. The cycle goes around, and the next request comes in and off we go again.

GIS databases can be created and used at almost any scale to address many questions. These can include:
Global scale- Continental or Ocean-specific ecosystems and climate dynamics and change over time. Data could be derived from a combination of satellites, in-situ sensors, high altitude aircraft, and could also include atmospheric, political, economic, and other relevant data. Modeling of potential scenarios and potential outcomes can be produced.
National scale- Many nations generate and produce national scale GIS datasets that are used for many purposes. The U.S. National Map (https://www.usgs.gov/programs/national-geospatial-program/national-map) is an excellent example, as is the French Geoportail (https://www.geoportail.gouv.fr). These data are produced by multiple agencies and are freely distributed to support many potential users, including national and state or departmental agencies, academic researchers, the private sector, and nonprofits. Data range from satellite and aerial imagery, environmental data, political, economic, health, and other diverse information.
Regional ecosystem scale- A project that encompasses a regional environment or ecosystem of varying possible dimensions. It could be of a size of some square km to hundreds of square km.
Local scale- Virtually every regional and local political entity in the developing world in North America and Western Europe have a GIS staff and database that support governmental activities ranging from use value taxation, infrastructure management such as roads and streets. These systems support diverse activities including economic development, police, fire, and public safety, public health and more.
Very Local scale- this could be a GIS for a study of a small individual pasture ecosystem of some hundreds of meters across, creating a detailed database of vegetation patterns, or a single archaeological site measuring tens of meters across.

GIS databases are independent of scale, and can be developed and used at scales ranging from the global to the local, and there are even GIS databases of Antarctica, individual watersheds such as the Chesapeake bay in the U.S., Mars, and the Moon. We often nest smaller and more detailed analysis areas within larger, less detailed, regional datasets.

Geomatics is a more recent term that is used to describe the functional integration of vector and raster GIS (discussed below), databases, remote sensing, LiDAR, drones, Global Positioning Systems (GPS), the internet, statistical analysis, decision support systems, the cloud, visualization, big data, in situ monitoring, AI, and much more. This is far more comprehensive than the original boundaries of GIS, and it is a powerful and quickly developing interconnecting suite of capabilities. Figure 11.2 shows some of the interconnected research domains that can be integrated within the geomatics framework. Figure 11.2 also shows the various, interconnected geomatics tools and technologies that provide us with a broad suite of integrated tools that do much more than just store and display digital maps. All of these, together, can be used to create a virtual model of reality for our use. We can create a virtual 'flight simulator' of data through time that we can use as a testbed for the analysis of complex processes and trends. We can test quantitative hypotheses and create new models as new data arrive or new theories are developed. This allows the exploration of multiple possible scenarios and their potential consequences before we actually make decisions and impact the environment.

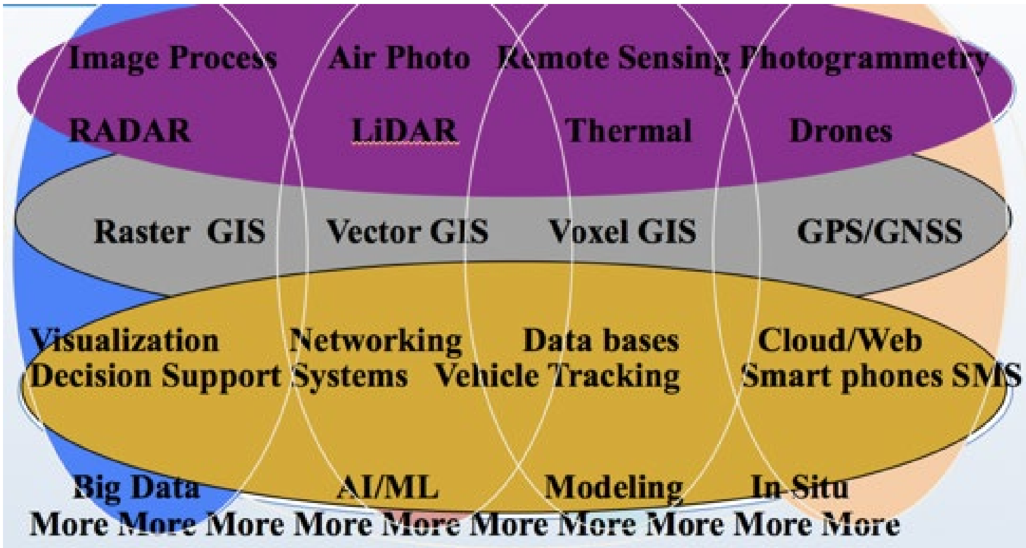


Figure 11.2 The interconnected domains that make up Geomatics today. Image from Scott Madry.

The basics of the use of HGIS

There are several sub-varieties of GIS. These include systems specifically designed for utilities networking and electrical power distribution, business marketing, defense, and more. For our purposes, we have also developed GIS systems that are specifically used for historical and regional environmental analysis over time, and these are called Historical GIS, or simply HGIS. The tools are the same, but the focus and data revolve around the incorporation of historical maps and aerial photos, population and ecological data, and all of the information that we can derive from these, as well as the quantitative analysis and visualization of spatial patterns of change over time. HGIS is an evolving discipline, and projects are growing in both sophistication and geographical extent around the globe (Piovan 2019).

For Historical Ecology projects, a GIS database can serve a variety of purposes. It supports equally well the preparation and conducting of field work, conduct of post field work spatial analysis, as well as providing graphics, mapping, statistical analysis, visualizations, the synthesis of various sources of data, and, ultimately, the integration and presentation of final results.

GIS Data: Vector and Raster

Anything that can be plotted on a map or located in the real world can be entered into a GIS database. We have two primary ways of storing, accessing, analyzing, and representing GIS data; vectors and rasters. Vectors, represented in figure 11.3, can be used to represent points, lines, and areas, called polygons, as a series of points that are connected by straight lines. Points by themselves, simply an X,Y pair of coordinates, can represent data such as individual trees, artifacts, or GPS field locations. Sets of points connected by lines can represent streams, road networks, or elevation contours, and sets of lines that close upon themselves to create areas can represent soil zones, vegetation communities, political boundaries, or property parcels. Points, lines, and polygons can represent most GIS data in a vector format, where the spatial and non-spatial data are stored in a database. GIS is a spatial spreadsheet, where we store tabular attribute data that are linked with a spatial component, such as lines representing the elevation of a contour line or the soil type of a polygon. The same feature can be represented differently, depending on the scale. For example, archaeological sites could be stored as points over a large area, or as polygons at a more detailed (larger) scale.

Raster data are totally different from vector in their structure, but can represent the same features. Rasters are two-dimensional arrays of numbers, and often represent features such as elevation, slope, aspect, and scanned maps and remote sensing imagery. Each cell has a specific area and each contains a unique value, stored in the database. Remote sensing consists of inherently raster (grid cell) data that are displayed as pixels on our computer screens, as discussed in chapter 13 on remote sensing. Modern computers all use raster displays, for example, and modern GIS software can easily store and use vector and raster data, and can convert files between either format. In general, vector data are a better representation of the human-built environment: property and political boundaries, building footprints, and things that have discreet edges. Raster data are generally a better representation of many aspects of the natural world: soils, natural vegetation zones, elevation, slope, and aspect. These are what are properly defined as continuingly varying surfaces, where there are no discreet edges to soil types or vegetation communities in the wild. So raster data better represent these types of features. We can do GIS analysis with either, but it is better to use the most accurate representation of the world that is possible, either as vectors or rasters. Computers are very good at analyzing two dimensional arrays of numbers, so raster analysis can be very quick and powerful for conducting complex modeling and analysis using a raster calculator. Figure 11.3 shows point, line, and polygon data represented as both vectors and rasters.

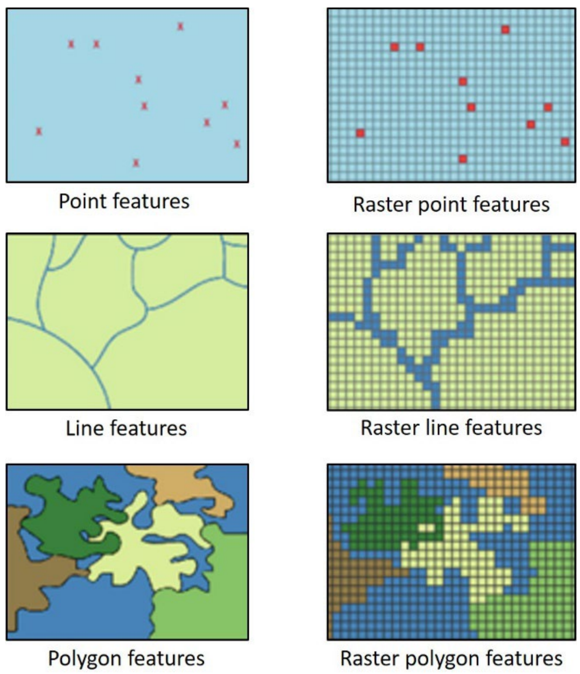


Figure 11.3. A simplified representation of the same points, lines, and polygons represented as both vector and raster data. Image courtesy U.S. Geological Survey.

In a GIS, we separate the complexity of the real environment, both human-built and natural, current and in the past, into individual, discrete layers, each representing a single category or feature type. This is often referred to as the "GIS Layer Cake" (Figure 11.4).

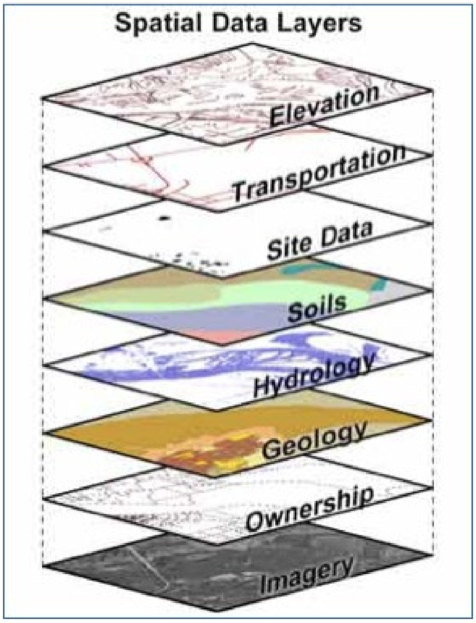


Figure 11.4 The GIS Layer Cake showing multiple data layers collected from different sources all georeferenced together. Image courtesy USGS.

The amount, type, scale, and date of your data depends both on what is available and what you require for your work. The vector data are linked with the tabular attributes of the data in a relational database, so that we can query and analyze these data in both a tabular and spatial sense. For example, "where are all the parcels larger than n hectares, and which are within 500 meters of a paved road, within 200 meters of a permanent streatm, within these three political jurisdictions". GIS is very much a spatial spreadsheet, and all vector data have a database engine behind it that stores and analyzes all the various categories of information that all are linked to locations on the ground.

Map scales

The scale of the source data is a vital concern, and maps of the same location created at different scales can look quite different and represent the features differently as well. Maps with a representative fraction (or scale) of 1:5,000 clearly have more detail compared with a map made at 1:100,000. All GIS data should be field verified as much as possible, and should never be considered to be 'true' until demonstrated to be so. Most vector GIS data are derived originally from paper maps, or, more recently, digital aerial surveys, from which vector maps are generated. Version management is an ongoing concern if you have more than one person working on the database, and it is vital to document the work done as you go, including which data was used for which analysis. It becomes very difficult to recall what was done by whom in long-term research projects, especially when students and researchers come and go over time. The ability to create and update metadata, or information about the data such as its source, date, scale, and how it was processed, are provided for in all GIS systems, so that you can document the process used to create new layers, the sources, dates, etc. All GIS data and maps are cultural constructs, created for a given purpose and within a specific time, technology, and organization, and so it is important to understand as much as possible the intent and technological limitations and perspectives of the creators of the data that you use. This includes you and your project colleagues.

Map Projections and coordinate systems

The world is (roughly) round, but maps are flat, and so there is a need to describe the nature of what a map actually represents in terms of both the scale but also how it represents the actual surface of the Earth. This is the science of geodesy, and it is a fascinating and complex field. The old saying in cartography is "All maps lie flat, therefore all maps lie", meaning that any flat representation of the Earth's surface has inherent spatial errors. Something has to be distorted. These distortions can be mathematically described, and maps are produced using various different map projections using different coordinate systems. There are hundreds of map projections and also many different coordinate systems, including Latitude/Longitude, Universal Transverse Mercator (UTM), and many national and state mapping grids (Snyder 1987). You should become familiar with those used in your study area, and use the right projection and coordinate system for your project. Modern GIS systems can easily convert data between these.

In a GIS, for it to be useful, all the layers are (or should be) georeferenced to the same map projection and coordinate system, so that all of the features on all the layers 'line up' appropriately. So that if you were to stick a pin down through all the layers, they would all be the same location on the Earth. The problem is that our data come from many sources, and in HGIS they come from many dates as well, and the data are often in different projections or, in the case of historical maps, may come with none at all. By separating and co-registering all of the data in this way, we are then able to recombine and analyze the data at will to achieve a better understanding of our world and of our impact upon it, in the past, present and future. This is the power of GIS.

GIS-related field work

It is very useful to conduct field work in support of your GIS, and, in the other direction, the GIS can support field work in a variety of ways. Field work can help verify the location of features and also can assist in georeferencing maps and photographs to field features. In the other direction, GIS can support a wide variety of field activities by providing field maps in either paper form or using a tablet or field computer. As discussed below, historical maps and other data can be directly viewed in the field as you move along, and you can actually digitize new maps 1 to 1 in the field using GNSS receivers.

Methods of data collection and data analysis

All maps are created based on field reconnaissance, or aerial surveys that are based on field knowledge. Conducting 'ground truth' is an important aspect of GIS work, because errors are always possible and we must ultimately connect what we actually see on the ground in the present day with what our data represent. Modern mapping agencies spend much time and effort to create accurate data, but the old GIS saying of 'Garbage In, Garbage Out" is always true, and errors will propagate through our GIS if they are not identified and removed or minimized. Central to our HGIS data are historical information derived from historical maps, archival aerial photos, and historical population, agriculture, and demographic data, as presented in the previous chapters. Field verification is vital to connect these representations of the past, such as old roadways or the location of mills and dams, with the present reality on the ground. A good GIS is never static, and we can create new individual files from each map, including vegetation zones, streams, ponds and water features, road networks, houses and buildings, mills, elevation contours, and other features, but this is all dependent on the map data available. Historical maps are fascinating, and are covered in detail in chapter 6, but they are also cultural constructs, created for a specific purpose, and may not contain all features on the landscape or be categorized in the same way as another map of the same area. There are many different scales of maps, and smaller scale maps (things look smaller at smaller scales) often generalize and omit features that are included in maps created at a larger scale (where things look larger). More information on cartography and historical maps is included in Chapter 6, and they are closely linked with HGIS.

All maps and GIS layers have an associated coordinate reference system (CRS) describing its projection and coordinate system. These can vary over time as cartography and geodesy have continued to evolve and improve over time. An understanding of the CRS of an input map is vital, as all paper maps must be scanned and georeferenced to our modern GIS database before we extract individual sets of features or conduct analysis. Good GIS database design is critical, and the old GIS saying of "Garbage In, Garbage Out" is even more true when working with historical data. It is important to understand what types of questions you want to address with your project data before you begin, so that you can pick appropriate data sources, and so that you can extract the individual classes of features, such as water features, roads, or buildings, into the correct categories to support your analysis (e.g. for hydrology: major rivers, permanent streams, ephemeral streams, canals, artificial ponds, springs, natural ponds, etc.) Good database design is important and much easier to do before you digitize features than after the fact. We have developed a new and improved process of georeferencing historical maps due to the difficulty of accurately locating features on the ground (Madry, Jones, and Tickner 2009). It is based on a localized process of 'rubber sheeting', where different sections of an old map are warped in different amounts and directions based on local modern features, rather than using a single warping process for the entire map.

Finding appropriate data for your project is always a challenge in HGIS, and the availability of such data varies widely by time, nation and region around the world. For North America and western Europe, there are many GIS deatasets and historical map sources available, with many already in digital format and available online, but the farther off you go, the more difficult it can be to find the data you require for your scholarly interests. Searching for old maps and documents is part of the fun in doing HGIS, but sometimes you must redefine your project goals and questions to seek to address, due to the lack of appropriate data for your study area, or you may wish to move to another location where better suited data is available. We sometimes have to create our own layers entirely if other data are not available.

Examples of the use of GIS in Historical Ecology projects

There are a growing number of projects using GIS in Historical Ecology projects around the world. Levin presents a good overview (Levin 2015) and a few more are added here. Some good examples are the North Orkney Population History Project (Jennings et al. 2019), and others in Italy (Gabellieri et al. 2015), California (https://www.sfei.org/content/delta-historical-ecology-gis-data#sthash.qlqAo8Ti.dpbs and https://www.sfei.org/programs/projects), the Columbia river basin of Washington state and Canada (https://www.fisheries.noaa.gov/resource/data/columbia-basin-historical-ecology-project-data), Canada, (https://niche-canada.org/2021/03/05/historical-gis-as-reparative-environmental-history-of-the-global-north-atlantic/), and Jordan (Zohar, M. 2019), and there are many more. There are several books on the subject with several moew examples (Gregory and Ell 2008), (Knowles 2002), (Knowles and Hillier 2008).

Integration with other data and into our GIS in our project

Our French GIS research dates back to 1986 and has continued ever since. GIS data are primarily spatial information, derived from GIS digital data, maps or remote sensing, along with their associated attribute information. But much of the data of interest to HGIS projects comes from historical records such as tax, birth, death, marriage, agricultural and economic records and more, as presented in the chapters above. We also have various geological and pollen core data, climatic data, archaeological data, and more. We need to integrate these data to the maximum extent possible, and our GIS system is the environment where we can do this.

Publications from our GIS research, including but not limited to our Historical Ecology work

Our French GIS database research has been fruitful, and to date, we have published papers on archaeological patterns and predictive modeling using GIS (Madry and Crumley 1990), Historical transportation networks and line-of-sight and intervisibility analysis of ancient roadways (Madry and Rakos 1996), the use of genealogical software (Jones 2009), mills, ponds, and water features in the study area (Madry et al. 2015), interdisciplinary collaboration (Jones et al. 2018), historical cartography and integration with GIS (Madry, 2006, Madry 2008, Madry, Jones, and Tickner 2009, and Madry et al. 2011), meadows and hay (Leonnartson et al. 2016), the use of Google Earth for archaeological site discovery (2007), digital terrain data (Madry and Wiencek, 1995), remote sensing and site detection (Madry 1991, Madry 2005), aerial photography (Madry 1987), and associated technical methods, among other topics. At present, we are working on a comprehensive book which contains the cumulative research work conducted over the past 20 years (Madry and Jones, 2024, in preparation). This will include chapters on forestry and forests, agriculture and animal husbandry, hedges and hedgerows, wine and vineyards (Figure 11.6), hemp and flax production, water, mills and ponds, and settlement patterns and transportation networks in our study area. Our work continues.

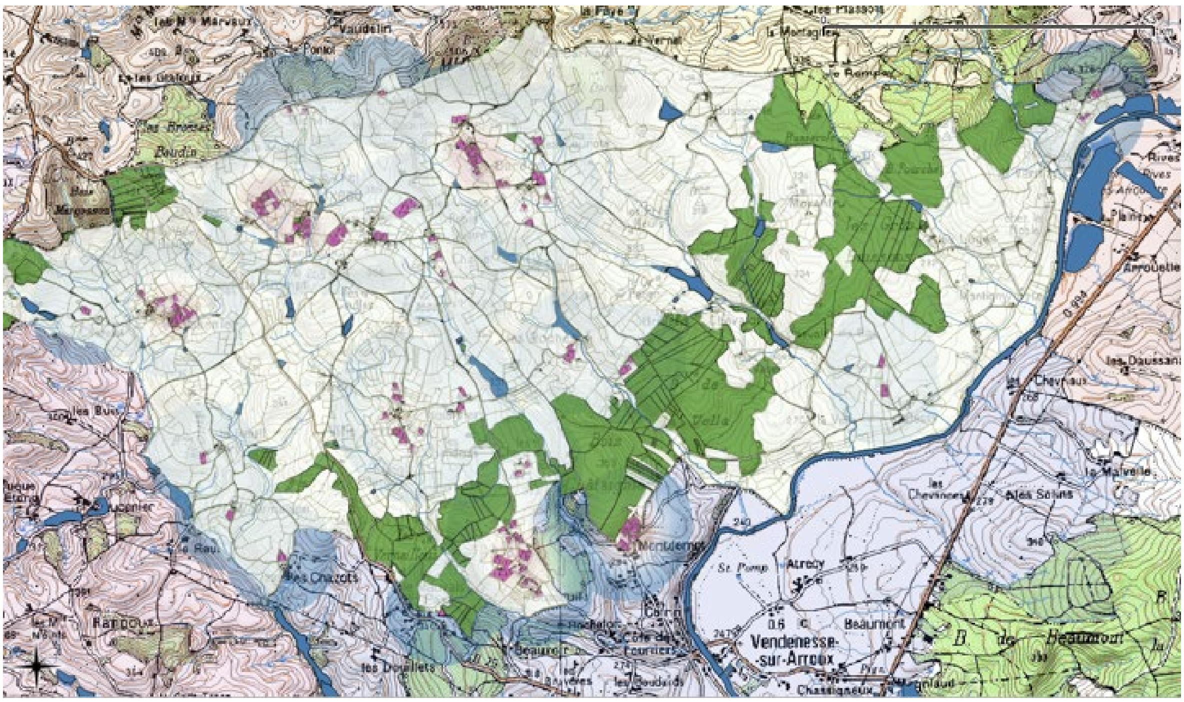


Figure 11.6. Vines displayed in purple and forests in green as of 1834 in Uxeau commune, France. Data derived from the 1834 cadastral maps and associated tax data, all displayed over the modern IGN topographic map. Image from our QGIS project database created by Scott Madry.

Limitations and benefits of working with these data. What we can do well and what we cannot

GIS is a very powerful tool, and current systems are both free to use and relatively simple to learn. But they are quantified digital data, which have their strengths and limitations. It does very well at measuring quantified data such as the relationships of soils and vegetation zones, distance zones to hydrology, measuring slope and aspect, how many parcels are taxed at a certain level or who owns how many fields and where, and for generating area measurements and statistical analysis of environmental and cultural variables. GIS is less able to deal with 'fuzzy' or 'soft' social questions and issues of meaning, context, social relationships, power, and equity. We have trouble creating "a typical Celtic settlement landscape", because we cannot really quantify what that means. But it can store the location and raw data of the site of ethnographic interviews, for example, and new capabilities are always under development.

Best practices and sources of errors and problems

One of the interesting and difficult issues in doing HGIS is that much of our data are derived from historical maps, old aerial photos, and other data that are significantly less spatially precise than modern digital mapping data. My experience is that the farther back you go the less accurate the data are, and so it is always best practice, if possible, to work backwards in your data, from the most recent to the oldest, in order to maximize the spatial accuracy and precision of your work in each step back. As mentioned above, we have developed an improved method for georeferencing historical features from old maps and aerial photos, as shown in Figure 11.7 (Madry, Jones, and Tickner 2009) due to the difficulties experienced in this process, and there are others working on this area as well.

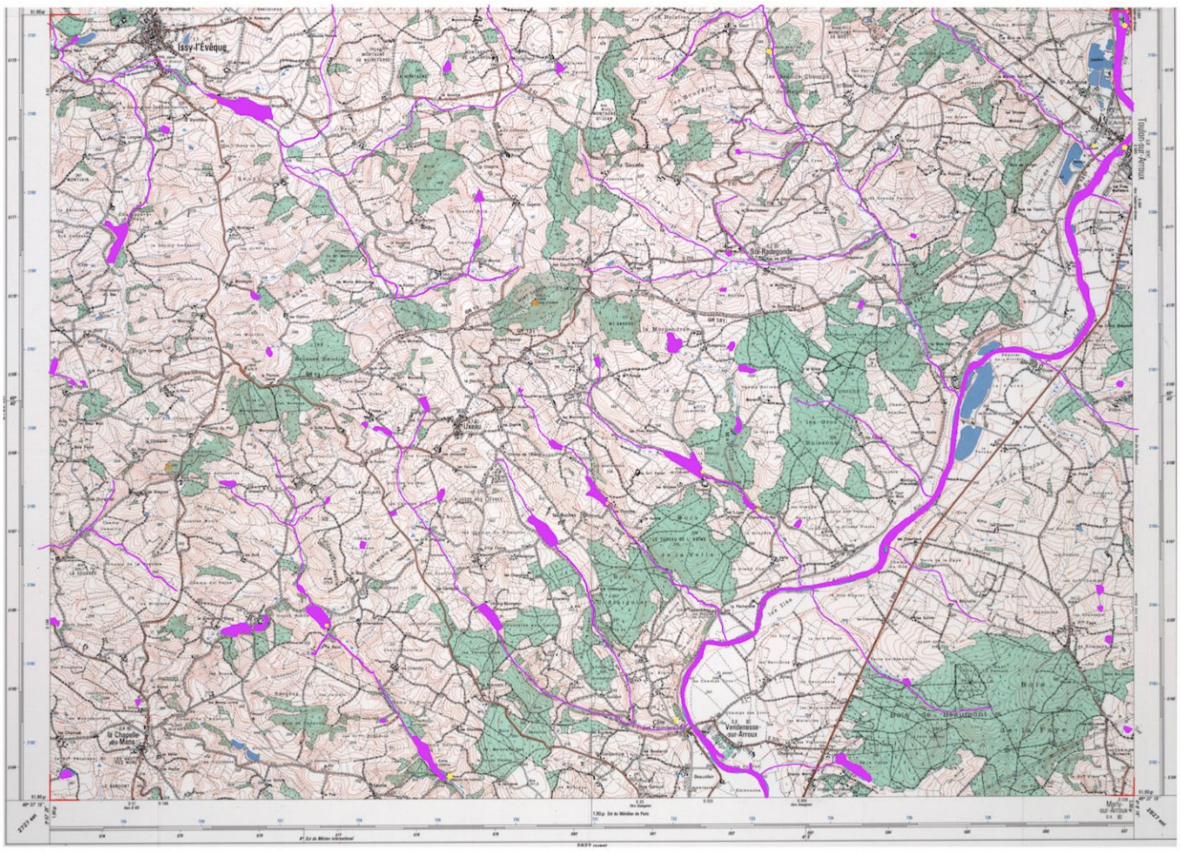


Figure 11.7. The 1759 hydrology, including rivers, streams and ponds, shown in pink, of the area re-registered to our master IGN topo map, using our new method. Image from our QGIS project database created by Scott Madry. This is far more accurate than the original version shown in Figure 11.11.

Sources of GIS data

When we began we had to manually digitize all of our maps, as there was no existing digital data available, but today there are many readily available digital sources of GIS data. But some freely available data may not be of an appropriate level of detail for your specific needs. Good places to look are national, state, and local archives, including national mapping agencies such as the USGS in the U.S. and IGN in France.

OpenStreetMap

There is no single, global GIS data repository, but the OpenStreetMap online wiki (https://www.openstreetmap.org) is about as close as we have today (Figure 11.8). It is an online wiki, where people can, free of charge, digitize and update their own local areas, and where all the data are freely available. People map their own local regions as they change and freely share these as a single, global detailed set of GIS data. It is the most accurate and detailed global GIS database today.

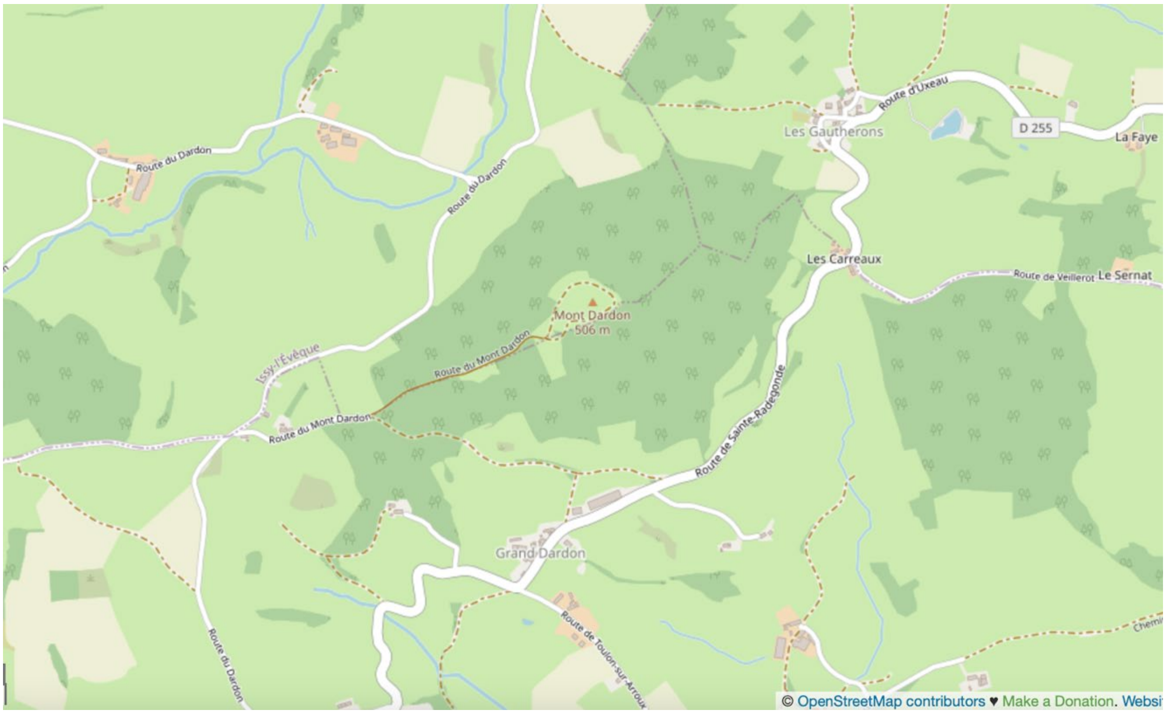


Figure 11.8. The OpenStreetMap view of Mont Dardon, France, showing detailed forest cover, roads, and settlements. Image courtesy OSM: (https://www.openstreetmap.org/search?query=uxeau%2C%20france#map=15/46.6758/4.0369).

Geofabrik

The Geofabrik organization, a commercial GIS business in Germany, takes a nightly download of all the OpenStreetMap (http://openstreetmap.org) global and very detailed GIS data, and converts it all into ESRI ArcGIS shapefiles, downloadable for free by nation and states from their website at: https://www.geofabrik.de/data/download.html. This is an excellent place to start to find detailed, current GIS data for your local area, no matter where you are in the world, but you can also look for data in national mapping agencies, local governments, NGOs, other researchers, university libraries, government agencies, and other sources. Often we create our own, specific data for our research needs if it is not already available.

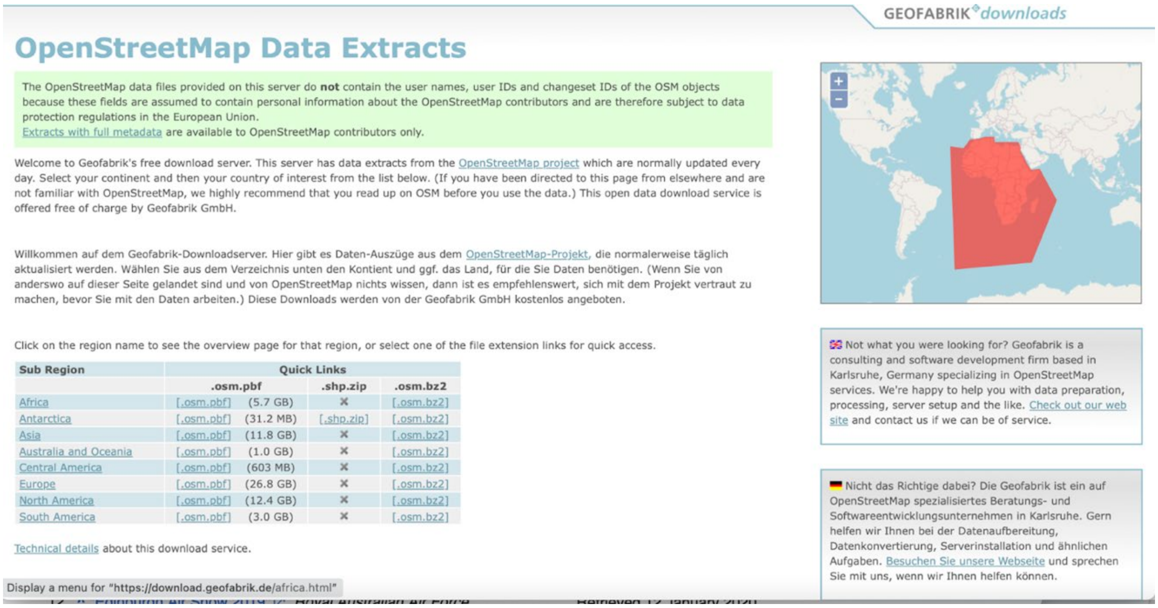


Figure 11.9. The Geofabrik.de OpenStreetMap extracts website (https://download.geofabrik.de)

Be careful of data copyright and ownership issues, the scale of the original maps or sources of the data, and do not use or share data for which you do not have a license or that is not in the public domain. Older data are often in obsolete or unused coordinate reference systems, so read the metadata (if present) and you may have to convert this using your GIS. GIS can be an excellent tool for explaining your work, goals, and results both within your project and more broadly to the public.

Cost and effort required, training needed, data size and complexity issues and software required

GIS has developed to be a very mature and capable technology, and is widely available and it is relatively simple to begin, but it is a complex technology and it can be difficult to become fluent and learning can be frustrating on your own. There are many 'how to' GIS books, blogs, and websites, including my book on QGIS (Madry 2021). There are also many online GIS training programs and universities and colleges offer courses as well, and many of these are available online. Most universities and many community colleges and other schools offer GIS training, and there are several excellent online options as well.

Open Source Alternatives, Free and Open Source Software (FOSS) GIS

GIS is a computer-based technology, and so it requires computers and storage, software, and data. Fortunately, things have progressed, and GIS work can be done using a standard desktop or laptop computer today, but faster systems, bigger monitors, and more storage are always good. The commercial GIS system ArcGIS, from the Environmental Systems Research Institute (ESRI) is the standard commercial GIS today. While ESRI and their products have largely created the current commercial GIS landscape, and continue to drive its use, there are significant issues with this model. ESRI is a commercial business, and their business is selling GIS, along with associated data, training, and consulting, all for a profit. Their software, and the other commercial remote sensing, relational database, and related tools, are very expensive, only work in the English language, only work in the Microsoft Windows environment, and are closed tools, in that you cannot actually see the code or know exactly how they work. Licenses are very expensive, and you cannot transfer or legally copy the code. Universities often receive free copies, but once you graduate or leave, you lose access and cannot use your data without purchasing a full commercial license. These restrictions are all reasonable for a commercial product in the commercial context, but this has led to the development of a vibrant and growing Open Source Geospatial community, that is, in many ways, disrupting the existing ESRI paradigm, and which is very appropriate for Historical Ecology research.

Open Source GIS has been around for a long time. The GRASS GIS, the Geographical Resources Analysis Support System, was originally developed by the U.S. Army Corps of Engineers, Construction Engineering Research Lab (USA-CERL) in Champaign, IL. It was first developed in 1982 for Army base environmental compliance, largely for NEPA (National Environmental Protection Act) compliance protecting cultural resources and endangered plant and animal species on military bases and Army Corps of Engineers managed lands, which is very compatible with Historical Ecology uses. GRASS was developed using the UNIX operating system, and it was the first, practical, Open Source GIS. As this was before the popularity of ESRI products, GRASS developed its own vector and raster data format and process of managing and displaying data, as it was a completely independent development. It gained very wide use both within various U.S. government agencies (US Army, NASA, National Parks Service, Soil Conservation Service, and more), as well as academic and even commercial users. In 1997 CERL was ordered to cease GRASS development and support, after complaints from the commercial GIS vendors (ESRI). GRASS development transitioned to European academics, and continues to grow strong, with thousands of users around the world. GRASS now has a very good user interface, and runs on Windows, Mac, and Linux. See https://grass.osgeo.org.

QGIS

Since GRASS was dropped by the US government and was later supported in Europe, other developments have occurred, including the rise of QGIS, which has assumed a leading role as the primary Open Source GIS system. QGIS, originally called Quantum GIS, was originally developed by Gary Sherman of Alaska in 2002. It was, at first, a simple data viewer, but quickly became a fully functional GIS system, and is today the most popular and most widely used Open Source GIS in the world (https://qgis.org). It is simple to use, faster and smaller than ArcGIS, runs in over 40 languages, and runs on Windows PCs, Macs, and several flavors of Linux. It even has a tablet interface useful for field data collection. It is a fully capable raster and vector GIS system, and can be used for complex analysis, including HGIS applications. It is quite simple to learn, and has a very understandable user interface. It is the primary GIS work environment of the author.

Benefits of Open Source

Free and Open Source Software (FOSS) GIS, and other applications, have many advantages beyond the fact that you do not have to pay for the software. In the Open Source model, anyone can play, no matter where or who you are, what language you speak, or how much money you have. Open Source is free as in lunch, and free as in liberty. You don't have to pay anyone to use the tools, and it is open, allowing for free sharing of tools and knowledge. Everyone can participate and share, and it puts us in charge of development. This also enables citizen science, local users, and other, nontraditional approaches to research, which is very appropriate in the Historical Ecology model. This means that academics and practitioners including all fields related to Historic Ecology, who have very specific research needs (and often smaller research budgets), can develop and share tools that are specific to our particular research interests that are not commercially viable or of interest to commercial software developers. It extends collaborations around the world, as many Open Source tools, like QGIS, work in over 40 different languages, and run on Windows, Mac, and Linux OS. This means that students, who benefit from the use of free licenses from ESRI while they are in school, can take their tools, data, and skills with them after they complete their education, where ESRI licenses will expire as soon as you leave school. It also means a much faster development and bug fixing cycle, as there are developers and collaborators around the world working on new tools, and we can actually see what the modules do, because the source code is open, and we can adapt and improve the code to our specific research interests. There are very active and growing archaeology, ecology, hydrology, and other user communities in the GRASS and QGIS communities, and people share developments and applications, and share ideas online and at conferences. There are many reasons why Open Source tools should be used by Historical Ecology researchers.

Most Open Source GIS tools, including QGIS, are Licensed under the GNU General Public License (GPL) that requires all derived products to become Open Source, and be made available under the same or similar license. This allows everyone to acquire and use the programs for any purpose, to study and modify the code, and to release these to the public. The only thing that you cannot do is to sell the software. There is also the GNU Lesser General Public License (LGPL), that allows the use of libraries in proprietary programs.

OSGeo

A major player in the Free and Open Source (FOSS) geospatial community is the Open Source Geospatial Foundation- OSGeo (www.osgeo.org). This was founded in 2006, and it exists to support the development of FOSS GIS software. GRASS, QGIS, and many other projects, over 200, are supported by OSGeo.

Cost and effort required, training needed, data size and complexity issues and software or equipment required

All you need is a reasonably capable computer and you can download QGIS and its related tools, and GIS data and historical maps and other data are now widely available online from many sources. There are many online learning opportunities, and also many books and workbooks as well (https://locatepress.com) as well as international and disciplinary online user groups and forums, YouTube videos, blogs, and conferences.

Multi-terabyte hard drives can be purchased for US$100, and that should at least get you started. I would suggest purchasing slightly more expensive solid state hard drives, as they are less prone to failure. Get two and rotate them as your active and backup drive to avoid losing data. Getting started is relatively simple, but it takes time and experience to get to where you can conduct complex modeling and analysis. Large format quality scanners for maps are more difficult to find, but many university libraries, and even many FedEx stores or other copy stores now have these. Including a GIS specialist in your Historical Ecology project is a very good idea, but you can begin to use these tools yourself.

Archiving data, physical and digital

Archiving and data management are major issues in HGIS projects. Multiple copies of our GIS database are retained by members of our team in different locations, to avoid loss through fire or accident. Our working database is named "GIS Final" as a project joke, because it is a living and growing thing like sourdough starter on the back of the stove, that seems to never be finalized. Our original paper maps are all stored flat in map drawers, and the various original and paper records are maintained by each researcher in the group who is responsible for that data. Digital archiving is a growing and important related field, and is covered in chapter 15. We must all participate in appropriate digital (and physical) archiving of our research materials.

Existing guidebooks, field guides, and tutorials

There are several very good resources for you to begin your own GIS journey. These include:

Principles of Geographic Information Systems (excellent basic textbook by ITC in the Netherlands) available online at:
https://webapps.itc.utwente.nl/librarywww/papers_2009/general/principlesgis.pdf

The QGIS main website with sample data and extensive tutorials https://qgis.org/en/site/

A gentle introduction to GIS: https://docs.qgis.org/3.22/en/docs/gentle_gis_introduction/index.html

My book: Introduction to QGIS Open Source GIS, with tutorials and sample data https://locatepress.com/book/itq

QGIS for Archaeologists: Getting Started
http://www.bajr.org/BAJRGuides/42_QGIS_StarterGuide/42_BAJR_Guide_QGIS.pdf

Relevance to Historical Ecology

The potential applications of GIS and Geomatics for Historical Ecology research should be evident. HGIS provides a digital context where data from many different sources and from different researchers from different disciplinary perspectives who are involved in a Historical Ecology project can share a commonly held and used source of data. These include information from historical documents, maps, field work, photos, geological data, and much more. All members of the team can have equal access and this is an important point. We all see the research area and the data through our own disciplinary filters and viewpoints, and looking at all of these data together truly can enable the transdisciplinary perspective that we all seek. We all see the same data differently.

Conclusions

GIS is one of the linchpins of our long-term French research program, now over 45 years old and still ongoing. Fortunately, the quantity, quality, and ease of access of our data, and the tools to analyze them have increased tremendously over the past decades that we have been working with these tools in our Burgundy research. But the process and goal remains the same, we seek to understand the complexity of the relationship between people and their environments over time, and our GIS is a unifying and central aspect of our work.

There are many issues that you should consider carefully when conducting this type of work. You must match the scale and quality of your data with the research questions you are addressing, and sometimes they do not match. You then either have to find additional data or revise your research questions or find an area that has the needed data for analysis. There are many technical issues to consider, and best practices should be learned and followed. Quality control must always be a primary concern, and we always have a second person review and check the GIS digitizing, tabular attributes, and analysis work that is done before it is cleared for use. This is a laborious and time-consuming process, but it is vital to the quality and reliability of our work. It is vital to maintain proper documentation of your work process and the data, as we are constantly creating new derived layers. Updating your metadata is vital, and keeping up with versioning of your data is key as well. With more than one person doing GIS work, you need to constantly ensure that you keep an up to date master version, and multiple, off-site backups are essential. All of this takes time, more time than you think. The new and evolving domain of digital archiving (Chapter 15), is a growing, if nascent, aspect of this work, keeping track of all of the GIS and other data used in large, complex, and long-lasting projects such as ours. The most important thing is that you can incorporate GIS into your Historical Ecology work, and it can play a central role in the management and analysis of your data. Free and Open Source (FOSS) GIS software and data now make these powerful tools much more available for Historical Ecology researchers around the world to learn and use, so just get started!

References

Abler, Ronald F. 1988. "Awards, rewards, and excellence: Keeping geography alive and well." The Professional Geographer 40.2 (1988): 135–140.

Conolly J., and Lake M 2006. Geographical Information Systems in Archaeology. Cambridge: Cambridge University Press.

Crumley, C., and W. Marquardt 1987. Regional Dynamics: Burgundian Landscapes in Historical Perspective. Carole L. Crumley and William H. Marquardt, editors. Academic Press, San Diego.

Gabellieri, Nicola & Panetta, Alessandro & Pescini, Valentina. 2015. GIS applications for environmental archaeology and historical ecology: Problems and potentialities the case study of Punta Mesco (Cinque Terre National Park - Italy). 211-212. 10.1109/DigitalHeritage.2015.7419497.

Gregory I, Don Debats, Don Lafreniere eds.: The Routledge Companion to Spatial History. Routledge 2018.

Gregory, I. Paul Ell 2008. Historical GIS: Technologies, Methodologies, and Scholarship (Cambridge Studies in Historical Geography) 2008 ISBN 978-0-521-67170-5

Jennings JA, Sparks CS, Murtha T. 2019. Interdisciplinary Approach to Spatiotemporal Population Dynamics: The North Orkney Population History Project. Hist Life Course Stud. 2019;8:27-51. PMID: 32346595; PMCID: PMC7186771.

Jones, E., Westin, A., Madry, S., Murray, S., Moen, J., Tickner, A., 2018. How to Operationalize Collaborative Research. Chapter in Issues and Concepts in: Historical Ecology, eds. Carole Crumley, Anna Westin and Tommy Lennartsson. Cambridge University Press. Pp. 240-275.

Knowles, A., Past Time, Past Place: 2002. GIS for history A collection of twelve case studies on the use of GIS in historical research and education. ESRI press.

Knowles, A, Amy Hillier eds.: 2002. Placing History: How Maps, Spatial Data, and GIS Are Changing Historical Scholarship 2008 ISBN 978-1-58948-013-1

Lennartsson, Tommy, Anna Westin, Anamaria Iuga, Elizabeth Jones, Scott Madry, Seth Murray, and Eva Gustavsson 2016. "'The Meadow is the Mother of the Field': An historical Agroecosystem Comparison of three European Landscapes." Martor: Museum of the Romanian Peasant Anthropology Review 21:103-126.

Jovanovic, D., & Oreni, D. 2021. The Methodology to Systematise, Present and use Historical Cartography: Potentials and Limits to Analyse and Enhance Widespread Historical Centres in Northern Italy. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.

Levin, N. 2015. Challenges and Possible Approaches for Using GIS as a Tool in Historical Geography Landscape Research : a Meta-analysis Review.

Madry S., 1987. "Remote Sensing in a Temperate Regional Archaeological Survey in France," in Regional Dynamics: Southern Burgundy from the Iron Age to the Present, edited by C. L. Crumley and W. H. Marquardt- published by Academic Press.

Madry S., 1991. "Un Emploe des Systemes de Teledetection et d'information Geographique dans une Analyse Regionale de Repartition Spatiales Archaeologiques," In: Archeologues et Ordinateurs, Lettres d'Information du Centre de Recherches Archeologiques. 17:1-11. Paris: Centre Nationale de la Recherche Scientifique.

Madry, S., 2005. Archaeological applications of remote sensing, in: Remote Sensing for GIS Managers, S. Aronoff, ed., ESRI Press, Redlands, California, pp. 376–383.

Madry, S., 2006. "Hic sunt dracones (Here be dragons): The Integration of Historical Cartographic Data into Geographic Information Systems." In: Between Dirt and Discussion: Methods, Materials, and Interpretation in Historical Archaeology. Steven N. Archer and Kevin M. Bartoy, eds. Springer, New York, pp 33-60.

Madry, S., 2007. "An Evaluation of Google Earth for Archaeological Aerial Prospection and Site Survey" in: Digital Discovery: Exploring New Frontiers in Human Heritage. CAA 2006. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 34th Conference, Fargo, United States, April 2006. Jeffrey T. Clark and Emily M. Hagemeister, Editors. 2007. Budapest: Archaeolingua. (ISBN 978-963-8046-90-1)

Madry, S., 2008. "Des gorilles du Rwanda aux sites archéologiques de la vallée de l'Arroux, Introduction aux nouveaux outiles de cartographie et d'analyse spatiale". in: "La Cartographie au Service de la Recherche et de l'Aménagement du Territoire", Centre Archéologique Européen, Glux-en-Glenne, France.

Madry, S. 2021. An Introduction to the QGIS Open Source Geographic Information System. A 220-page book by Locate Press. https://locatepress.com/book/itq

Madry, S., Cole, M., Gould, S., Resnick, B., and Seibel, S., 2004. Procedural Manual for Phase I of the Archaeological Predictive Modeling Project, Document submitted to NCDOT by Environmental Services, Inc., Raleigh, North Carolina.

Madry, S., Cole, M., Gould, S., Resnick, B., Seibel, S., and Wilkerson, M., 2005. A GIS-based archaeological predictive model and decision support system for the North Carolina Department of Transportation, in: GIS and Archaeological Predictive Modeling, M. W. Mehrer and K. Wescott, eds., Taylor & Francis, London, pp. 317–334.

Madry, S., and Crumley, C., 1990. An application of remote sensing and GIS in a regional archaeological survey, in: Interpreting Space: GIS and Archaeology, K. Allen, S. Green, and E. Zubrow, eds., Taylor & Francis, London, pp. 364–380.

Madry, S., Jones, E. and Tickner, A. 2009. "An Improved Extraction of Historical Cartographic Features into GIS: A French Case Study". Scott Madry, E. Jones and A. Tickner. in: Proceedings of the Computer Applications in Archaeology conférence, Williamsburg, Va. USA March 22-26, 2009. In Proceedings, and available online at: http://www.caa2009.org/articles/Madry_Contribution186_a.pdf

Madry, S., Jones, E., Tickner, A., and Murray, S. 2011. "Une Micro-Histoire de la Terre et de L'Utilization des Resources- L'integration des GIS-H (Systemes d'information géographique historiques) et des données qui y sont liées en Bourgogne du sud". in: Le Monde des Cartes, Rapport Cartographique National revue de Comité Français de Cartographie No 208, pp. 75-94, Juin 2011.

Madry, S., Jones, E.,Tickner, A. and Murray, S. 2015. Water and Landscape Dynamics in Southern Burgundy: Three and a Half Centuries of Water Management in an Agricultural Landscape" Journal of Water History 7(3):301-335.

Madry, S., and Rakos, L., 1996. Line-of-sight and cost surface analysis for regional research in the Arroux River Valley, in: New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research, Center for Archaeological Investigations, Occasional Paper No. 23, H.D.G. Maschner, ed., Southern Illinois University, Carbondale, pp. 104–126.

Madry, S and Wiencek, R. 1995. "Applications of Digital Terrain Data, Archival Maps, and Historical Aerial Photographs for Regional Archaeological Analysis," (with R. Wincek) Paper presented at the 23rd annual meeting of the Computer Applications in Archaeology conference, Leiden, the Netherlands, April 2, 1995.

Ott, T. and Swiaczny, F. 2001. Time-integrative GIS. Management and analysis of spatio-temporal data, Berlin / Heidelberg / New York: Springer.

Piovan, S. 2019. Historical Maps in GIS. The Geographic Information Science & Technology Body of Knowledge (1st Quarter 2019 Edition), John P. Wilson (Ed.). DOI: 10.22224/gistbok/2019.1.4(18) (PDF) Historical Maps in GIS. Available from: https://www.researchgate.net/publication/331071936_Historical_Maps_in_GIS [accessed Sep 20 2021].

Snyder, J. P. 1987. Map projections: A working manual. United States Geological Survey Professional Paper. Vol. 1395. United States Government Printing Office. doi:10.3133/pp1395. ISBN 9780318235622.

Zohar, M. 2019. Follow the road: historical GIS for evaluating the development of rout3es in the Negev re3gion during the twentieth centur. *Cartography and Geographic Information Science,* 46,(6), 532-536, https?/doi.org/10.1080/15230405.2019.1577176

CHAPTER 12

AERIAL PHOTOGRAPHY

SCOTT MADRY

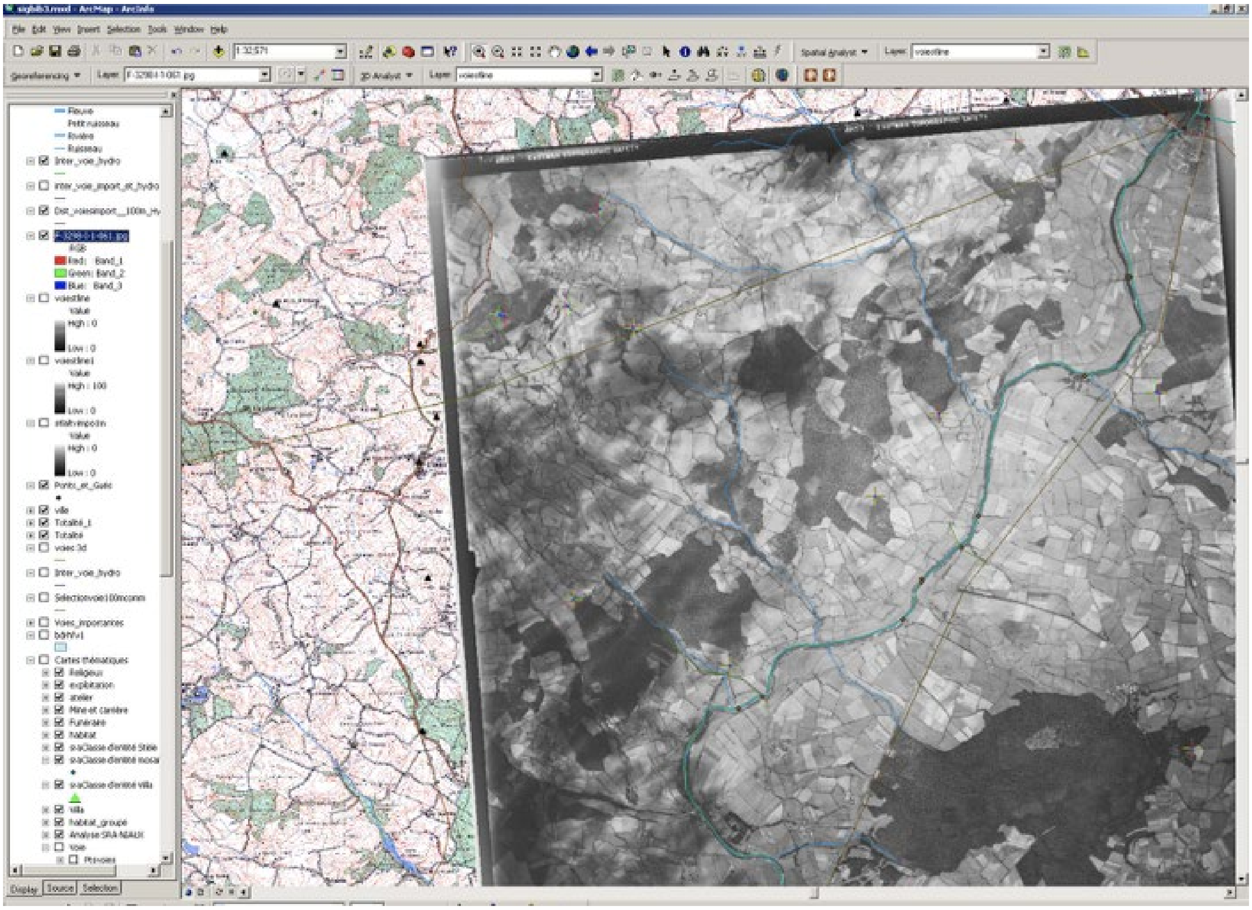


Image 12.1 A 1945 U.S. military aerial photo of France, georeferenced and overlaid on a GIS map.

This chapter will introduce the methods, techniques, and approaches of the analysis of various types of aerial photography in support of Historical Ecology research. Historical and modern aerial photos are a rich source of information for such research, and they are available widely around the world. Precise measurements from aerial photographs led to the development of the technical process of photogrammetry, and accurate topographic maps were able to be created and updated over vast areas. Digital technologies led to the development of digital sensors in aircraft which have revolutionized our ability to map and analyze our world. New developments, including the use of low cost drones and LiDAR-generated microtopographic data, hold the potential for revolutionizing our ability to analyze the environment over time. This chapter will present an overview of these technologies, and their current and future application to Historical Ecology. Data from projects will be presented.

Disciplinary underpinnings and perspectives

The disciplinary underpinnings and perspectives are broad, and include cartography, geography, photogrammetry, geodesy, and multiple individual applications including archaeology, forestry, agriculture, ecology, and water quality. It traditionally has been considered a 'team sport' with individuals working as a part of a larger group, but this is not always true, and individuals can conduct aerial photo acquisition and interpretation work with sufficient training. It includes both the field research activities, including gathering 'ground truth', as well as doing the analog interpretation or digital image processing of the data in the lab and the production of various maps. Detailed vegetation and land cover/land use maps can be derived. For Historical Ecology projects, it is a good idea to include a person with photo interpretation and remote sensing training to support the overall project goals. This can often be the GIS person, skilled in both, as they are closely related and are often taught together. Most current GIS software is capable of handling the basic processing of aerial images, but advanced processing may require dedicated digital photogrammetry tools.

The Origins and Principles of Remote Sensing

Remote sensing is the science and art of obtaining information about some object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the subject under investigation. It is remote and sensing. Our senses of sight and hearing are remote sensing, while our senses of touch and taste are direct sensing. Since ancient times, people have always looked for the high ground, and have used the landscape to get a view of potential hunting opportunities or threats. The Iron Age hillforts in our study area in Burgundy are examples of this use of the landscape to view the surrounding region. Later, people developed ways of viewing our world using balloons, kites, and even pigeons to take aerial photographs (Figure 12.1).

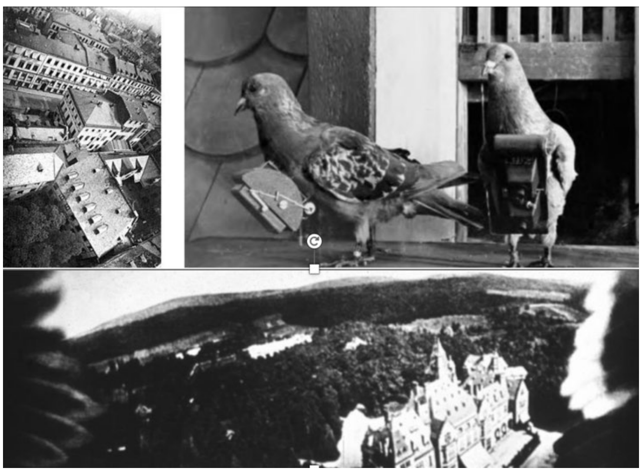


Figure 12.2. Pigeon cameras and resulting photographs by Julius Neubronner (1852-1932) in Germany. Note the wingtips in the edges of the bottom photo. Photo courtesy U.S. Library of Congress.

The development of the airplane and aerial cameras created the first aerial remote sensing systems that could systematically map our world, and great strides were made in World War I and II in aerial mapping. Today, we have new and low cost aerial drone systems that bring new capabilities to research projects (Wilson, 2000). This has revolutionized our ability to map and analyze our planet Earth for many different applications, including for Historical Ecology and related research.

Methods of collection and data analysis

The use of historical and modern aerial photographs in historical ecology involves locating appropriate data sets and acquiring access to them, visual analysis and interpretation, and (for historical aerial photos) scanning, georeferencing, and extracting land use and land cover features and entering these into your project GIS, very much in the same process discussed in chapter 6, on historical cartography. For digital airborne data, the process is similar, except the data are already in digital format, and can be often acquired without cost over the internet. Some data come already georeferenced but others are not and require this step. The images then require digital processing to extract the data of interest for use in your project GIS. Generally, aerial satellite imagery provides us a detailed temporal series of land use and land cover maps, useful for a variety of historical ecology interests (Morgan et al. 2010).

Aerial photography and Photogrammetry

Aerial photographs are simply any photo taken from an aerial perspective. They can be acquired from aerial towers, balloons, drones, light aircraft, high altitude jets, satellites, or any aerial platform. The first known aerial photo was taken from a balloon in France in 1858. The history of this is fascinating, and goes back to the first balloon flights and they were even used in the U.S. civil war (1861-1865), but really advanced during the first and second world wars when huge technical developments were made. (https://papa.clubexpress.com/content.aspx?page_id=22&club_id=808138&module_id=158950).

Aerial photos fall into to categories, oblique and vertical. Oblique aerials are photos taken at any angle, while vertical photos are taken pointing directly down below the camera, at what is called the nadir point. There is a very long history of aerial archaeology in Europe, dating back to just after the first world war (Bourgeois and Meganck 2005, Wilson 2000) and thousands of archaeological features have been discovered from light aircraft at low altitude conducting 'aerial prospecting' while flying low over the landscape. The later development of GPS and digital cameras significantly improved these efforts, and they continue today.

While any aerial photo can contain useful information, vertical mapping photos taken from high quality digital mapping cameras provide accurate and detailed measurements of the land and vegetation. Originally, black and white photos were taken, but later color and even color infrared films were developed. Today, most aerial cameras are digital. Photogrammetry is the art and science of deriving accurate measurements using aerial imagery, and it is the basis for the production of nearly all modern topographic maps produced today by national mapping agencies around the world.

Scale

Like maps, aertical aerial images each have a specific scale, or representative fraction, which means that a given distance on an image equals some other actual distance on the ground. This can be represented as a fraction, such as 1/25,000, or as a ratio such as 1:100,000. Things look large in large format photos (1:2,500), and things look small in small format images (1:100,000), and these terms are often used incorrectly. The actual scale within an aerial photo actually varies somewhat with the altitude out from the center point (radial distortion) and also with terrain variations within the image (topographics distortion), and these must be corrected photogrammetrically. The lower the altitude of the camera, the greater the relative distortion.

Photo interpretation

Aerial photos accurately acquire an image of what is below, but the features on the landscape are often difficult to interpret without training and experience. These are the skills of the photo interpreter, and it is a very useful skill for those conducting Historical Ecology projects, especially using a series of historical aerial photos. There are several common aspects to photo interpretation, and these include interpreting: the shape of a feature on the ground, the size of features, the tone (for black and white) or color, of vegetation for example, patterns such as tree plantations or golf courses, shadows indicating tall features, texture, time changes between photo dates, and association, meaning if you see an airport runway, a large building next to it is likely a hangar or terminal, where the same size building at an ocean port is likely to be a warehouse. Each of these, individually and together, allow a trained photo interpreter to determine settlement and land use and land cover information and other useful information from aerial photos (Philipson 1997). Archaeologists have used these indicators to locate habitation sites, old roadways, field boundaries and other features around the world, and foresters and ecologists can investigate vegetation communities and their changes over time.

It is important to understand that the scale of the questions and data are vital issues here. We can accurately map, for example, regional land use and land cover over large areas, and the changes in these over time, using aerial photography and remote sensing imagery, covered in chapter 13. We can accurately map the major categories of forest, pasture, and agricultural crops, etc., and can map the human occupation in terms of building, roads, and structures, but for many ecological questions related to Historical Ecology, such as the detailed mapping of relevant species, this must be done on the ground by trained biologists. Such 'ground truthing' as it is called in the remote sensing community, allows us to improve the quality and detail of large area mapping using aerial photos and remote sensing.

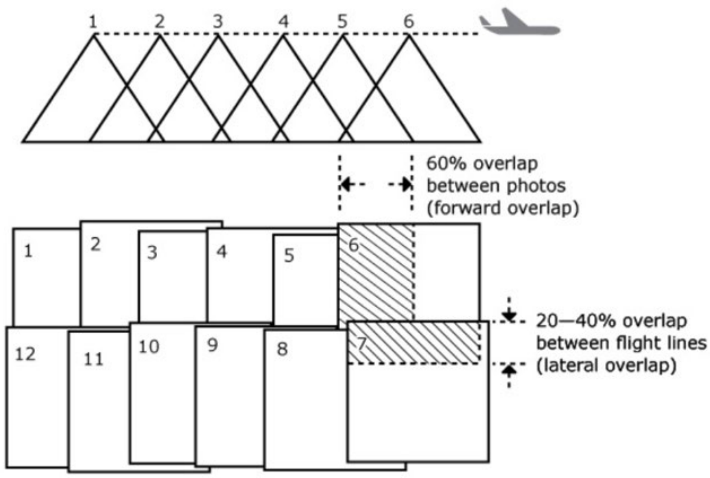


Figure 12.3. Overlapping aerial photographs. Image courtesy Natural Resources Canada (https://www.nrcan.gc.ca/maps-tools-publications/satellite-imagery-air-photos/air-photos/national-air-photo-library/about-aerial-photography/concepts-aerial-photography/9687)

Most vertical mapping photos are taken in carefully aligned parallel flight lines, which overlap both along the flight line and with adjacent lines (Figure 12.3). Each photo, traditionally measuring 9 x 9 inches, or 22.86 cm on a side, is assigned a unique identification number which includes the date, flight line, and photo number. Large maps are prepared showing the coverage of the aerial survey for easy reference. This overlap provides the interpreter the ability to see the world in 3-D using a simple optical stereo viewer (Figure 12.4). A stereo viewer uses parallax, the difference in the angle to features on the ground from the center of each individual photo. Our eyes and brains process this into an exaggerated 3-D view of the landscape, which is very useful for photo interpretation, allowing us to see the relative height of forests, structures, or other features. It takes a bit of getting used to, but can be learned quickly and is a very helpful skill in the field and in the lab.

One of the great benefits of aerial imagery is that these were widely acquired around the world dating back to the 1920's and 1930's for aerial mapping projects, and they have been reacquired at regular intervals up to today. Where available, these provide us with time series data going back for nearly 100 years. Many of these have been scanned and are available in digital format from government sourcers over the web. Others are only available as prints or with a printing cost. Your national mapping agency is your best place to begin looking (USGS in the USA, IGN in France, Natural Resources Canada in Canada, Lantmäteriet in Sweden etc.) And many of these have geographical data portals available online for searching and downloading data, including historical aerial photos and remote sensing images. There are also extensive archives in Western Europe of aerial reconnaissance photos taken during World War ll by all sides of the conflict. The availability varies around the world, so you will have to check for your local study area.

Some of the benefits of aerial mapping photos include the long time frame covered, higher detail (identifying individual trees and structures), the simplicity of manual analysis, and the recent availability of color or color infrared films that discriminate vegetation types better than older black and white images. Some of the limitations include the small area covered by each photo and the need for many photos to cover a given study area, local lighting, season, and time of day differences, variable scale and parallax within each photo, and the difficulty in patching together large photo mosaics accurately to cover large areas. These problems were addressed later by satellite remote sensing, discussed in the following chapter, where large areas can now be imaged in a single frame.

Figure 12.4. A 3x manual stereo viewer.

Examples of how different remote sensing techniques and sources have been used in our research in Burgundy, France.

There follows several examples of how different aerial photo techniques and data sources have been used in our long-term Historical Ecology research in Burgundy, France.

The author has conducted aerial research in this area since 1978, using a wide variety of different datasets and analytic methods. These range from flying low-level aerial surveys and visually interpreting vertical mapping photos, to using a variety of remote sensing data and their analysis using various digital image processing techniques (Madry 1983, 1987, 1998, 1991, 2005, 2007, 2008). The following section will give examples of how different types of aerial photography have been used in our historical ecological research in Burgundy. Similar uses can be applied in any spatial context around the world, and here are many such examples in the literature.

Figure 12.5. A low level oblique aerial photo of Mont Dardon, taken in 1979, showing the traces of an old Celtic roadway (darker gray line) at the top center of the image. Photo: Scott Madry.

Aerial Surveys and Aerial Archaeological Prospection

Archaeological and other environmental features may be visible from the air, or from an aerial perspective. The four primary ways this occurs are shadow marks, soil marks, positive crop marks and negative crop marks, as shown in Figure 12.6. Shadow marks appear in the early morning or early evening, when small variations in terrain cause linear or angled shadows to appear. They are very ephemeral, and may only last a few minutes from a given perspective. Old roadways and field boundaries are often found in this way. A similar mark is the snow mark, when, after a snow, linear stretches of snow or melted ground are briefly visible. Soil marks are visible as different colors of soil. These can be caused by digging of road ditches or other human activities. Positive and negative vegetation (or crop) marks are the most common source of locating archaeological or historical features from the air. Negative crop marks are seen where you have, for example, a buried stone foundation below the modern soil layer. Crops or vegetation cannot get their roots down through the rocks, and so, especially in times of drought or other crop stress, there will be a line or angle or circle of reduced vegetation growth that is clearly visible from the air. These are quite difficult to see from the ground. Positive crop marks are the opposite, and are seen as a darker green, indicating more vegetation growth. This can occur in a lower, wetter area, or in a location that was once an animal pen, containing more nutrient rich soils, or post holes for an ancient structure, which catches additional rain and fosters improved growth. All of these are accentuated by drought or plant stress. They are also very ephemeral, and what may be visible from one angle on one day of one season may be invisible the next week. This ephemeral character is one of the frustrations of aerial archaeology, and it requires frequent revisiting of the same location. Each year a different crop, at different stages of growth, may make visible features below the ground, or not. Buried features like rock foundations can be up to a meter below the current surface and still be visible as crop marks (Figure 12.9).

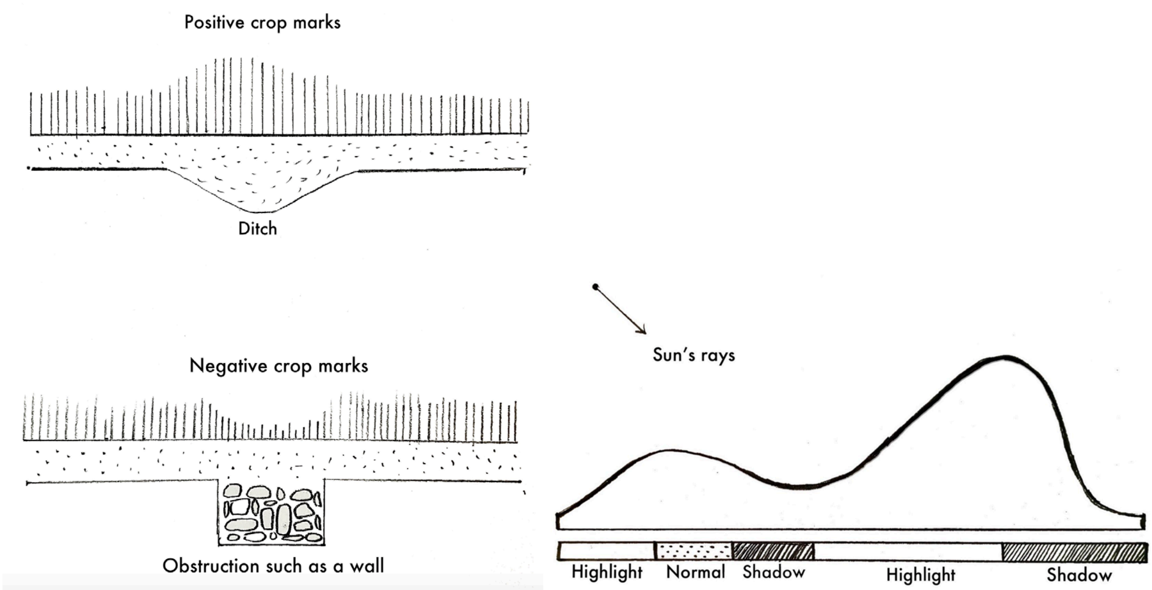


Figure 12.6. The primary sources of archaeological feature identification from the air: shadow marks, positive crop marks, and negative crop marks (soil marks not shown). Sourc: https://en.wikipedia.org/wiki/Aerial_archaeology.

Figure 12.7. A French Robin aircraft used in aerial prospection in France.

The photos in figure 12.9 were taken from a Cessna 172 light aircraft in the summer of 1979, which was a very hot and dry summer in France. A Gallo-Roman villa complex that we discovered is visible. The negative crop marks, with less vegetation, clearly show the outline of the stone wall foundations of the large structure. At upper right is a positive crop mark, probably indicating an animal pen or other feature where the soil contains more natural fertilizer and is more conducive to modern crop growth. At lower right is a pile of stones from the site on the surface, with curved marks made by a tractor raking over the stones.

Figure 12.8. A ground photo of the Gallo-Roman villa, taken later the same day as the photos in figure 12.9. The linear negative crop marks are clearly visible, but the larger pattern of the building structure is not discernible from the ground. Large amounts of Gallo-Roman era roof tile and pottery were visible on the surface. A person is walking at left for scale. Photo: Scott Madry.

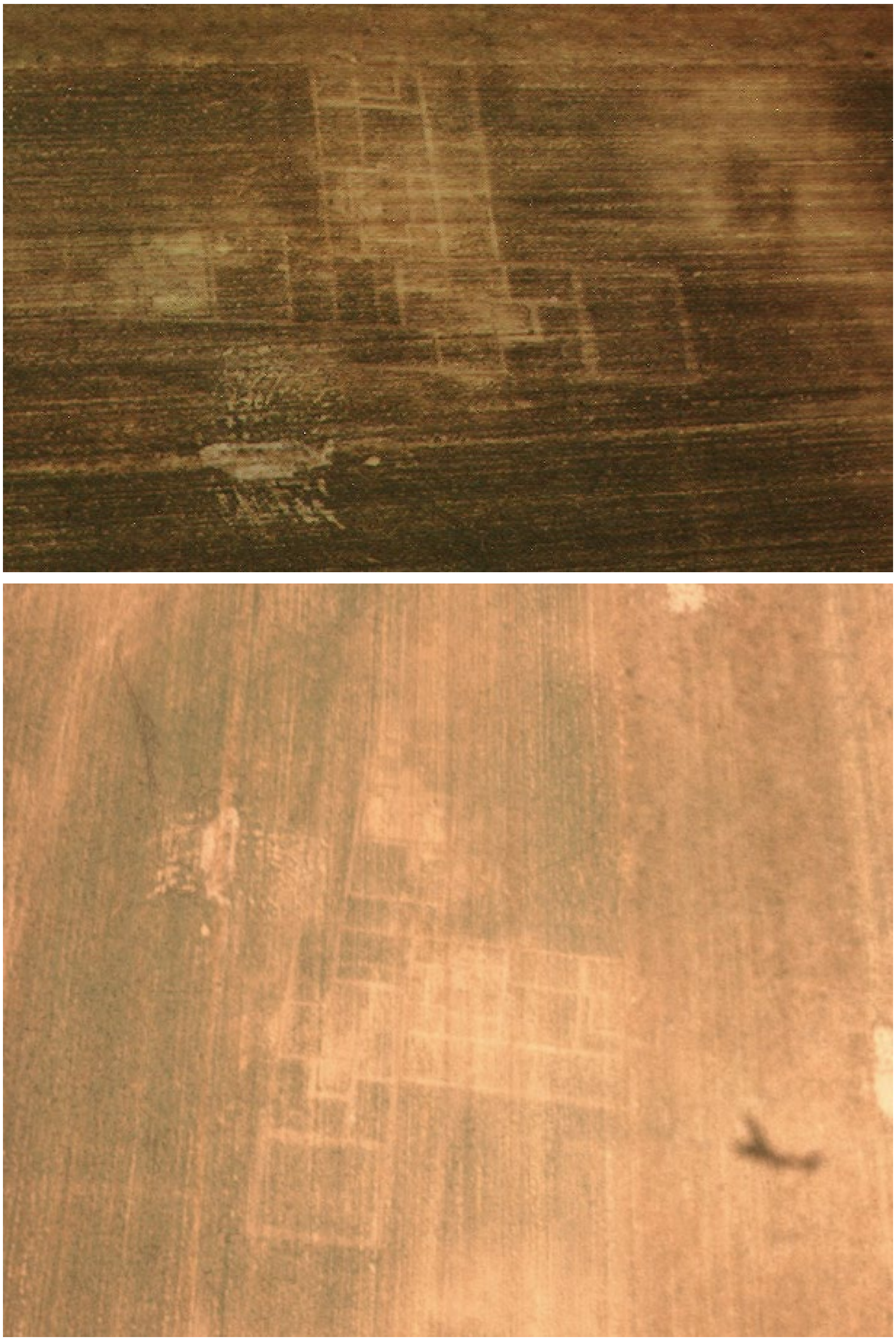


Figure 12.9. A Gallo-Roman villa located in 1979, with the shadow of the aircraft at right. Photo: Scott Madry.

Old roadways are useful features to locate in many ways, in that they connect communities and populations, and are often easily identified from the air (Figures 12.10 and 12.11).

Figure 12.10. Top: The route of an old Roman road indicated in the 1759 Cassini map. Bottom, the roadway as identified on the ground. Photo: Scott Madry.

Figure 12.11. An old roadway running through the landscape, as discovered in 1979 from the air. Negative crop marks are in the center of the road, and positive, darker green lines are on both sides, representing ditches on either edge. Photo: Scott Madry.

The 1759 Cassini map of our area indicates several ancient Roman road segments that were known or visible at that time. We used these maps, our aerial photos, and field visits to locate some of these features which were not known in the modern era (Figures 12.10 and 12.11). These were then added to our project GIS system and used to try to piece together the ancient land use and settlement patterns in the area.

Using Google Earth and other similar internet map viewers, as discussed below, has largely replaced this aerial process, but it was and is great fun to zoom over the beautiful French fields and to fly out of the small, grass airports and interact with the French aviation community. But ultimately, the cost and unreliability of the method outweighed its utility, and the analysis of high resolution satellite images remotely is much more productive, if less fun.

Google Earth Photo Analysis and Archaeological Site Prospection

The author has been one of the originators in the use of Google Earth and similar internet-based high resolution imagery apps for archaeological site prospection and analysis (Madry 2007). The advent of freely available, high resolution imagery viewers with world-wide coverage and frequently updated imagery has enabled site prospection and other work around the world from any computer with a good internet connection. This tool is also very useful for a wide range of purposes, including vegetation determination and change over time, locating old roadways, agricultural production, and other applications. Planning field work, local travel, and accessing rural areas efficiently are also easily planned using Google Earth's directions, and using streetview can provide a ground-eye view along roads (alas, it is not yet fully available in our very rural region of France and in many rural locations around the world). You can also overlay your GIS data in Google Earth by converting them to .kmz or .kml format for direct viewing in Google Earth. In the other directions, Google Earth files are also usable in all standard GIS environments. Google Earth has now also been joined by Bing Maps, Apple Maps, and other free, high resolution internet imagery viewers available over the internet. Viewing your region in each of these is often beneficial, as they have imagery of different sensors, dates, and seasons, and allow for comparisons over time using different imagery. Be careful about the user license limitations of these imagery sources.

The author has used these tools for several years now to conduct aerial archaeological site prospecting not only in Burgundy, but also in other parts of France, Europe, and also in Peru and South Africa. Over 200 archaeological sites, roadways, looted sites, and other features have been identified, documented, and shared with appropriate local authorities. One benefit is that newly located features can be easily saved as a placemark and shared by email, and once opened, it will automatically open Google Earth and display the location. You can then use Google maps to get driving directions to the spot. The simple ability to systematically survey a large area for the vestiges of ancient land use and sites from any computer with high speed internet anywhere in the world is a powerful tool (Figure 12.12 and 12.13), and documented in our previous research (Madry 2007).

Figure 12.12. Several Iron Age features in Burgundy that were discovered using Google Earth, including two square structures, rectangular field divisions, and an ancient road at the upper right. Image courtesy Google Earth.

Figure 12.13. A large Gallo Roman era villa rustica in Burgundy, located using Google Earth. This site is readily visible on some Google Earth dates (top) but nearly invisible on others (bottom), which is a common aspect of such ephemeral features and their appearance in aerial imagery. Photos courtesy Google Earth.

Existing vertical mapping aerial photographs are very useful for several types of regional analysis that are useful for Historical Ecology. They represent different dates and times of year, cover a very large area, and can be analyzed using stereoscopes to both magnify and also to show the area in three dimensions so that subtle changes in topography are seen. For example, vertical aerial mapping photos in France are available from the IGN (Institute Geographique National), and there are various dates available going back to the 1950's. More recent color and color Infrared photo sets are also available for free download from the IGN website. We have acquired several sets of these for analysis. Similar data are available in other nations, but it varies widely, so you will have to do your own search for your study region.

IGN Vertical Mapping Photos

The French IGN mapping agency has recently scanned and made available for free a series of historical aerial photos on their Geoportail website (https://www.geoportail.gouv.fr/). These date back to the 1950's, and several more recent images are Color Infrared (CIR) images that are very useful for discriminating forest and other vegetation types (Figure 12.19). They were the basis for all of the modern 1:100,000, 1:50,000, and 1:25,000 topo maps, beginning in 1951 in our area, and all of the more recent vector IGN GIS data. IGN now has a very sophisticated and ongoing process of acquiring digital aerial imagery of all of France on a revolving 5-year schedule using state-of-the-art digital airborne digital imagery systems.

Figure 12.19. 1946 aerial photo of the Celtic Iron Age hillfort of Mont Dardon, devoid of vegetation, displayed over a digital elevation model. The ramparts are visible. Original image courtesy IGN, 3-D image from our QGIS database.

New Directions: Aerial Drones and Airborne LiDAR

The technologies of aerial remote sensing continue to advance rapidly, and there are many new and interesting capabilities that are directly relevant to Historical Ecology research. Low cost and portable aerial drones are revolutionizing our ability to quickly acquire low cost aerial imagery without the use of expensive aircraft and pilots, and camera-carrying drones are now a regular component of many field research programs around the world (Meyer et al. 2015).

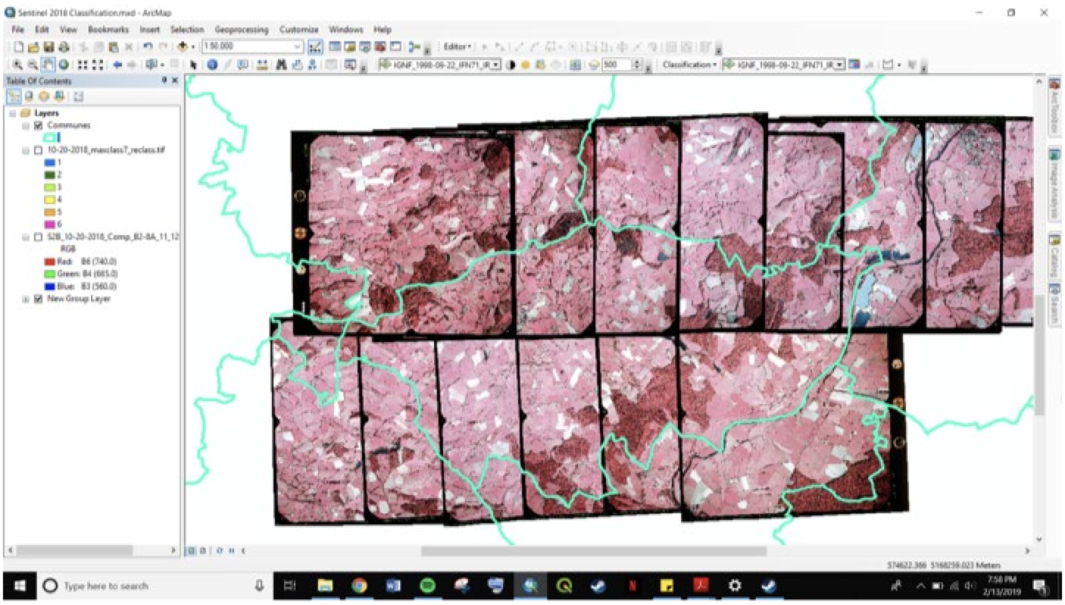


Figure 12.20. 1998 IGN digital Color Infrared Aerial photograph mosaic, centered on Uxeau commune. Mont Dardon is at top center. Commune boundaries are shown in green. Color IR is useful in discriminating between different forest and vegetation communities. The forest areas show the different pine vs hardwood areas. QGIS image by Scott Madry.

Figure 12.21. An Airborne Drone remote sensing system in the field. Image courtesy Cornell University. https://smallfarms.cornell.edu/2019/01/remote-sensing-shows-promise-for-vegetable-growers/

Drones range in size and cost from tiny hand-held units that can be purchased for a few hundred dollars to complex and expensive remotely controlled aircraft costing hundreds of thousands. These can be controlled in real time in the field, allowing the researchers to decide the time and season of image acquisition and to collect concurrent ground truth data. Drones can access areas difficult to reach on foot, and can be programmed to acquire exactly the same flightlines repeatedly on different dates. Many have modular payload bays, which allow for quick and simple swapping out of different sensors and payloads. There are drone flight planning modules available in QGIS and other GIS software, so that aerial data can be acquired and integrated directly into your project GIS. Drone applications and capabilities will only continue to grow, and will continue to become important parts of Historical Ecology projects as prices drop and capabilities increase.

LiDAR, Light Detection and Ranging

LiDAR, Light Detection and Ranging, is active laser light remote sensing in the visible portion of the spectrum, and it is revolutionizing archaeological, forestry, and other field surveys around the world. It provides detailed Digital Elevation Models (DEMs) accurate to a few centimeters. These show minute variations in topography, including data acquired through dense forest canopies. The vegetation can be digitally stripped away, showing detailed (cm precision) ground topography. Alternatively, forest composition and canopy cover can be extracted and analyzed in great detail (Figure 12.22).

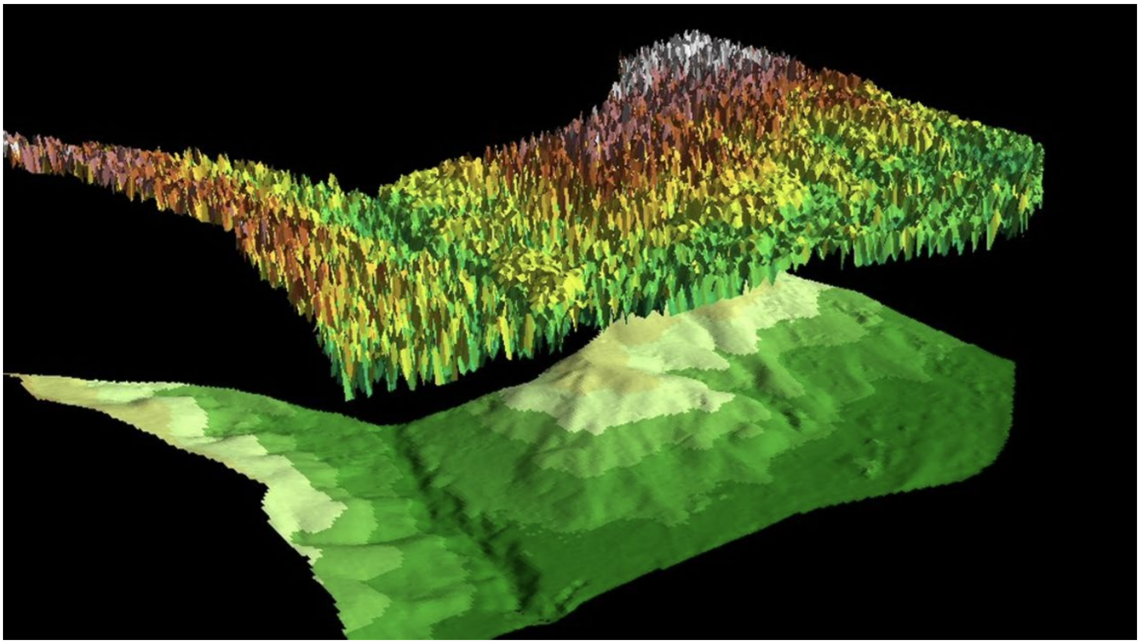


Figure 12.22. A 3-D airborne LiDAR image with vegetation (top) and stripped of vegetation (bottom). Image courtesy Foresttech https://foresttech.events/new-advanced-lidar-on-a-fixed-wing-uav/

This is revolutionizing archaeological and ecological prospecting in many locations. In MesoAmerica, hundreds of archaeological sites, roads, and other features have been located through the thick jungle cover, and minute topographic variations can be identified (Chase et al. 2012) as shown in figures 12.23 and 12.24 from Clermont-Ferrand, France.

Figure 12.23. An oblique aerial photo of the Iron Age oppidum of Gervogie outside modern Clermont-Ferrand, France . Oblique aerial image courtesy INRAP. https://www.inrap.fr/les-fortifications-de-l-oppidum-de-gergovie-14441#

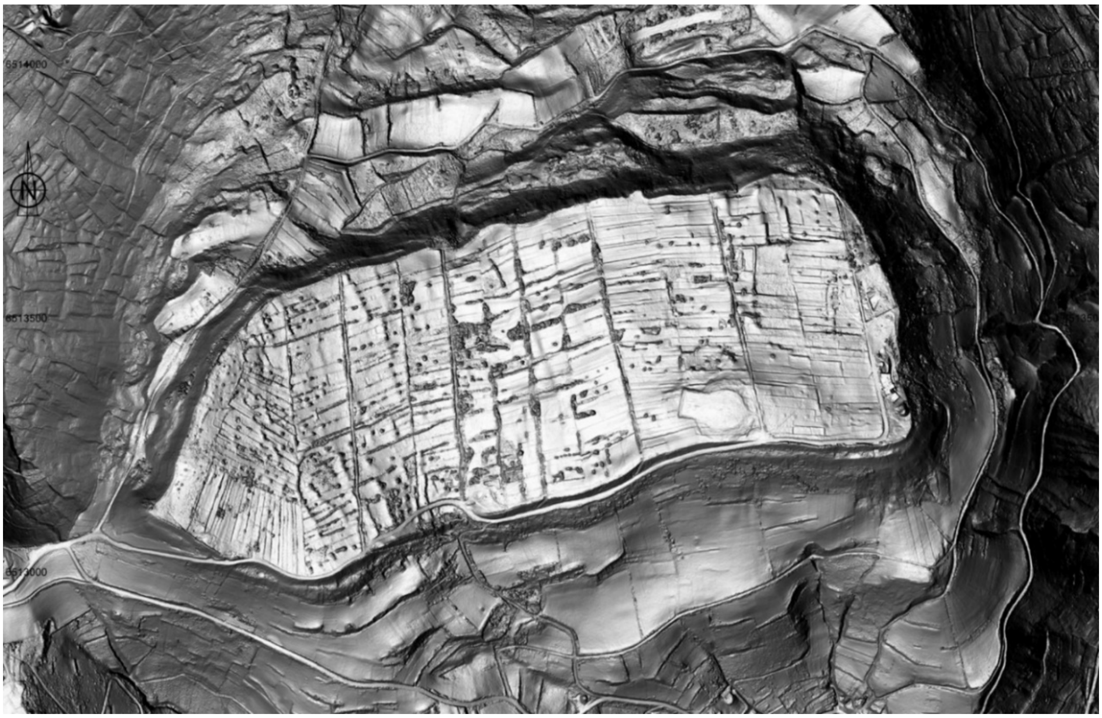


Figure 12.24. A vertical airborne LiDAR image, with the vegetation stripped away, of the same oppidum, showing small internal details of structures, ramparts, and more. Image courtesy INRAP: https://www.inrap.fr/les-fortifications-de-l-oppidum-de-gergovie-14441#

and https://historicengland.org.uk/images-books/publications/using-airborne-lidar-in-archaeological-survey/heag179-using-airborne-lidar-in-archaeological-survey/

Relevance to Historical Ecology

The potential applications of aerial photography, both historical and current, for Historical Ecology research should be evident. The examples presented here have focused on a long-term archaeological project, but aerial photography and air photo analysis have contributed and deepened our Historical Ecology knowledge of our study area in Burgundy. We investigated the changing nature of the vegetation, land use, and land cover over time in order to better understand how different cultures, with different levels of social organizations and technologies, both formed their environment and were, in turn, formed by them; how they were both limited and enabled by their physical environment, and how their levels of social and technological organization interacted with their local world and beyond (Madry 1987).

In order to investigate, and hopefully better understand, these questions, we used many integrated approaches and technologies, including ground surveys searching for evidence of archaeological sites such as structures, roads and ceramic concentrations, linked together with low-level aerial surveys and the analysis of vertical mapping air photos using stereoscopes in the lab, all searching for evidence of previous settlement patterns such as the visible remnants of roads, field boundaries, defensive structures, and habitations. By locating and mapping these according to their cultural affiliation, we were able to create regional maps of the settlement and transportation networks for the Iron Age, Gallo-Roman and early Medieval periods. These were used in our GIS analysis create archaeological predictive models which were used to both focus our future aerial and ground surveys in the area, as well as to better compare and contrast the differences in these patterns. Aerial photography played a key role in this process, by identifying both vegetation zones and vestiges of archaeological sites and transportation networks from the past that have, in some cases, been modified or completely destroyed by modern development.

Through our use of archival mapping photos from 1945, we were able to make general vegetation and land use maps from the end of World War II, which was used in our long term analysis of the changing patterns of forest use, ponds and mills, vines and wine production, and agricultural and settlement patterns over a 270 year period (Madry et al. 2015). It specifically informed us regarding the severe environmental impact of the war and of the German occupation, particularly on local forest resources (Madry et al. in preparation) and the recent impact of severe droughts. Historical aerial mapping data gives us a view of the region that is older than we can acquire using modern remote sensing systems, which reach back to the 1970's at best.

By mapping our best interpretation of the vegetation and human occupation, again using multiple integrated data including historical maps and pollen analysis, we investigated these changing patterns of settlement and land use in order to better understand these complex and interacting patterns over time, which has been the source of multiple publications. By using multiple aerial photography techniques, we learned much about the changes and continuities of vegetation and human settlement in the study area, which directly address our Historical Ecology interests. Future aerial technologies, including the routine and low cost use of drones and emerging technologies such as LiDAR data acquired from such drones, have the potential to advance new and currently unaddressed questions in Historical Ecology, including detailed regional vegetation community composition, detailed forest composition, hedgerows, hydrology, new archaeological discoveries, and more. Clearly, aerial photography in all its many forms is a powerful tool for Historical Ecology researchers, and we hope that you will consider how these can assist you in your work, wherever and whatever that may be.

Conclusions

Aerial photography is the oldest form of remote sensing, and data are widely available around the world, going back many decades. It can be conducted from many platforms and it can reach back into the past and extend our understanding of our environment and human settlements and land use and land cover. We are also seeing a new generation of use with inexpensive drones and powerful LiDAR, thermal, and multispectral systems that are generating new, inexpensive, and useful datasets for our use. Detailed environmental and cultural features can be extracted, and data can be integrated directly into your project GIS for analysis. Time series, fly-throughs, and visualizations can also be created and the detailed vegetation data can be used to improve satellite image classifications and other uses, as discussed in the following chapter.

Today, there are multiple freely available datasets of aerial imagery, all available to researchers free of cost via internet download. Other aerial and satellite data are also available for a fee, including data with pixels of only 15 cm. The archives of aerial photo data reach back to the 1920's in many parts of the world, but this varies. Vertical mapping photos, oblique, low-level aerials, and available high resolution satellite images are readily available today and can play an important role in Historical Ecology research. Each of these datasets have different and useful characteristics, and there is an important benefit in acquiring and analyzing different types of data over different seasons and years. This is referred to as the 'multi' concept. There are also, and equally importantly, Free and Open Source Software (FOSS) photogrammetry, drone management, image processing and image analysis tools to process these data and integrate the results into your GIS environment. Many nations make their archives of aerial photographs publicly available in print and digital formats, and acquiring your own data with drones has become a very cost-effective tool for field research.

Data Sources and Resources

There are several excellent basic remote sensing books available, here is a freely available one from ITC in the Netherlands:
(https://webapps.itc.utwente.nl/librarywww/papers_2009/general/principlesremotesensing.pdf.

Many universities offer hands-on classes and remote learning courses as well, and there are many tutorials and training materials available online and on YouTube and similar sites.

QGIS Open Source satellite remote sensing analysis code and tutorials
https://fromgistors.blogspot.com
https://fromgistors.blogspot.com/2018/02/basic-tutorial-1.html

Sources of Aerial Photography and Imagery

Sources of historical aerial photos:
USGS Aerial Photography site https://www.usgs.gov/centers/eros/science/usgs-eros-archive-aerial-photography-aerial-photo-mosaics?qt-science_center_objects=0#qt-science_center_objects

The U.S. National Archives aerial photography site (over 35 million aerials from 1918 to 2011 from the US and foreign lands during wars. Includes many German photographs https://www.archives.gov/research/cartographic/aerial-photography

UK National Collection of Aerial Photography https://ncap.org.uk

IGN French geodata site https://www.ign.fr

The IGN Geoportail https://www.geoportail.gouv.fr

US Library of Congress https://www.loc.gov/collections/?fa=subject:aerial+photographs

Sources of LiDAR data https://historicengland.org.uk/images-books/publications/using-airborne-lidar-in-archaeological-survey/heag179-using-airborne-lidar-in-archaeological-survey/

References

Bourgeois, J. and Meganck, M. (eds.) 2005. Aerial Photography and Archaeology 2003. A Century of Information. Archaeological Reports Ghent University 4. Ghent: Academia Press.

Chase, Arlen F., Diane Z. Chase, Christopher T. Fisher, Stephen J. Leisz, and John F. Weishampel 2012. Geospatial revolution and remote sensing LiDAR in Mesoamerican archaeology PNAS August 7, 2012 109 (32) 12916-12921

Goddard, George: 1969. Overview. Doubleday, New York

Cowley, David, Standrig, R and Abicht, M. eds. 2010. Landscapes through the lens : aerial photographs and historic environment. Oxbow books, Oxford, UK

Madry, S. 2008. Des gorilles du Rwanda aux sites archéologiques de la vallée de l'Arroux, Introduction aux nouveaux outiles de cartographie et d'analyse spatiale". in: "La Cartographie au Service de la Recherche et de l'Aménagement du Territoire", Centre Archéologique Européen, Glux-en-Glenne, France.

Madry, S. 2007. An Evaluation of Google Earth for Archaeological Exploration and Survey, in: Clark, J.T. and E.M. Hagemeister (eds.) Digital Discovery. Exploring New Frontiers in Human Heritage. CAA2006. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 34th Conference, Fargo, United States, April 2006. Archaeolingua, Budapest, pp. CD-ROM 329-337.

Madry, S. 2005. Archaeological Applications of Remote Sensing. In: Remote Sensing for GIS Managers, Stan Aronoff, ed. ESRI Press. Redlands, California.

Madry, S. 1990. An Application of Remote Sensing and GIS in a Regional Archaeological Survey" (with Carole L. Crumley) in Interpreting Space: GIS and Archaeology, K. Allen, S. Green, and E. Zubrow, eds. Taylor & Francis, London.

Madry, S. 1987. Remote Sensing in a Temperate Regional Archaeological Survey in France, in Regional Dynamics: Southern Burgundy from the Iron Age to the Present, edited by C. L. Crumley and W. H. Marquardt- published by Academic Press.

Madry, S. 1983. Remote Sensing in Archaeology." Archaeology Magazine, May-June, 1983 (pp. 18-19).

Madry, S., E. Jones, A. Tickner and D. S. Murray. 2015. Water and Landscape Dynamics in Southern Burgundy: Three and a Half Centuries of Water Management in an Agricultural Landscape. Journal of Water History 7(3):301-335.

Meyer, Dominique, Eric Lo, Aliya Hoff, Mike Hess, Falko Kuester 2015. Utility of low-cost drones to generate 3D models of archaeological sites from multisensory data. Presented at The 80th Annual Meeting of the Society for American Archaeology, San Francisco, California. 2015 (tDAR id: 395037)

Morgan, Jessica, S. Gergel, J. Morgan, S. Gergel, N. Coops 2010. Aerial Photography: A Rapidly Evolving Tool for Ecological Management BioScience, Volume 60, Issue 1, January 2010, Pages 47–59, https://doi.org/10.1525/bio.2010.60.1.9

Perisset, M. and A. Tabbabh 2007. Interpretation of thermal prospection on bare soils August 2007 Archaeometry 23(2):169 - 187.

Philipson, Warren R. 1997. Manual of Photographic Interpretation (2nd ed.). American Society for Photogrammetry and Remote Sensing. ISBN 978-1-57083-039-6.

Scollar, I. A. Tabbagh, A. Hesse & I. Herzog 1990. Archaeological prospecting and remote sensing. [Topics in remote sensing 2.] xviii 1990. Cambridge & New York: Cambridge University Press; ISBN 0-521-32050-X

Staerck, Chris (ed.): 1988. Allied Photo Reconnaissance of WWII. PRC, London,

Stanley, Roy. 1981. World War II Photo reconnaissance. Scribner, New York.

Wilson, D. R . 2000. Air photo interpretation for archaeologists, London: The History Press. (2nd edn.). ISBN 0-7524-1498-4

CHAPTER 13

SATELLITE REMOTE SENSING AND DIGITAL IMAGE PROCESSING

SCOTT MADRY

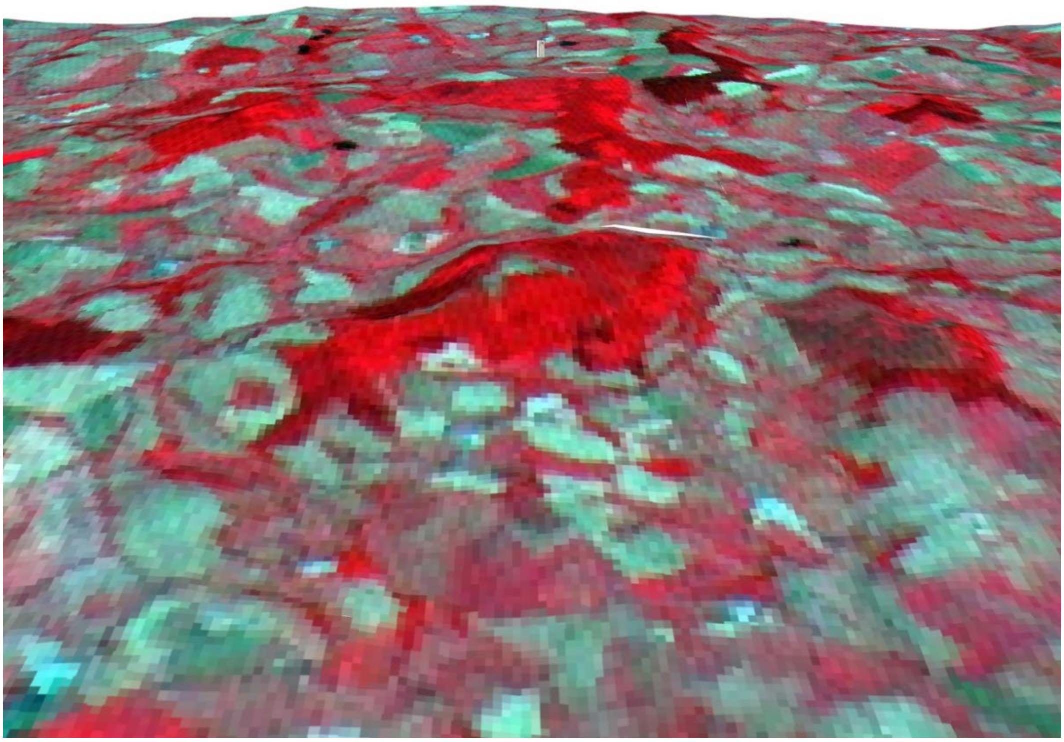


Figure 13.1. A satellite infrared image of Mont Dardon, France taken by the Japanese Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) dated 16-08-2002. Overlaid on a Digital Elevation Model in QGIS

This chapter will introduce the uses and analysis of satellite remote sensing and digital image processing in support of Historical Ecology research. Remote sensing is the collection of data from a device not in contact with the subject of investigation. It originated soon after the first balloons and aircraft were developed, as described in the previous chapter about aerial photography. The advent of modern digital technologies led to the development of digital sensors in aircraft and, more recently, in satellites in orbit, which have revolutionized our ability to map and monitor our world. Today, modern governmental and commercial Earth observation satellites image the world on a daily basis, and much of this data is now available without cost or at minimal cost to researchers via the internet. Powerful Open Source digital image processing software can process these data into land use and land cover data and time series of these, which are clearly useful in Historical Ecology research. New systems with improved capabilities are constantly being developed. This chapter will present an overview of these technologies, and their current and future applications for Historical Ecology. The chapter is separated into satellite remote sensing and digital image analysis sections, and examples from our ongoing work in Burgundy are presented.

Disciplinary underpinnings

The disciplinary underpinnings and perspectives are broad, and include photogrammetry, space sciences, digital image processing, electrical engineering, computer science, geodesy, and these are used in multiple individual application disciplines including agriculture, archaeology, cartography, ecology, forestry, geography, atmospheric science, and water quality. It traditionally has been considered a 'team sport' with individuals working as a part of a larger group, but this is not always true, and individuals can conduct photo interpretation and remote sensing work with sufficient training and the appropriate data and tools. It includes both the field research activities and gathering 'ground truth', as well as doing the digital image processing of the data in the lab and integrating these into the larger research context for analysis. This often involves integrating the data into the project GIS for further analysis. For Historical Ecology projects, it is a good idea to include a person with photo interpretation and remote sensing training to support the overall project goals. This can often be the GIS person, skilled in both, as they are closely related and are often taught together.

The Fundamentals of remote sensing

As mentioned in chapter 12, aerial photos have several limitations, including the cost, number of photos required to cover a large area and the variations in sun angle and time of year in aerial photo datasets, but the advent of the space age has led to the modern era of digital satellite remote sensing. Today, numerous satellites provide daily, global, high and moderate resolution imagery of our planet, covering the entire planet on a daily basis. These provide cost effective data that can be readily processed and integrated into GIS systems using available commercial or Open Source tools. Satellite images do not go as far back in time as aerial photo data, but they can be acquired and processed very quickly over large areas.

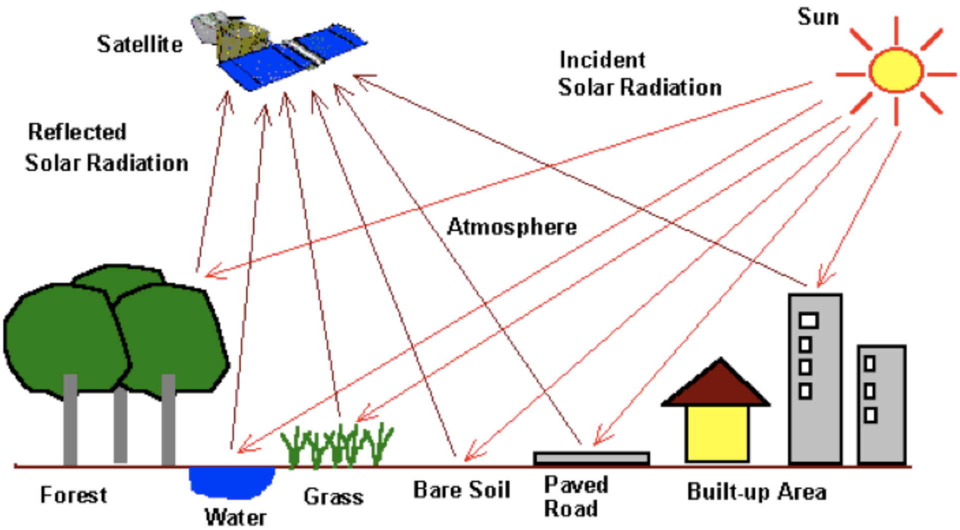


Figure 13.2. The process of passive space remote sensing. Image courtesy of Canadian Space Agency.

Passive remote sensing

The basic passive remote sensing process is shown in figure 13.2. The Sun's radiation strikes the Earth's surface and some small amount is reflected off the surface, back up through the atmosphere, and is focused on the detectors of the satellite's sensor.

Digital sensors on satellites record the number of photons striking it as it sweeps along its orbital track, hundreds of kilometers above the surface of the Earth, zooming along at over 28,000 km per hour. This photon count is converted to an electrical current (voltage), and then to a digital number that is stored onboard the satellite and then sent to the ground for processing. This is done for each tiny area of the Earth as the satellite passes over. A prism is used to separate the light into specific wavelengths or bands, which are useful for determining the makeup of the 'target'. These data are recorded onboard and are later telemetered down to the ground for further processing.

Active remote sensing

A different approach is active sensing, where we have our system send out a pulse of energy, often in the microwave (RADAR) or optical (LiDAR) spectral regions, and record the reflected energy for analysis. Active systems are very different, in that they send out their own pulses of energy, and so they can be acquired at night or through clouds. RADAR systems produce very different images, and LiDAR has revolutionized archaeology in deeply forested and jungle areas, as it is able to penetrate through foliage to map minute variations in the ground topography, as briefly presented in chapter 12. A high resolution satellite RADAR clearly shows in detail various land use and land cover categories (Figure 13.3).

Figure 13.3. A 25 cm pixel very high resolution airborne RADAR image of an airfield in Germany. Fields with different agricultural vegetation and houses at left, an airfield at center, and a forested area at right. Image courtesy DLR, the German Space Agency.

These active systems require additional image processing, but provide us with another way to view the environment and can be used together with other imagery to contrast and compare the differences. The basic difference between active and passive remote sensing systems is shown in figure 13.4.

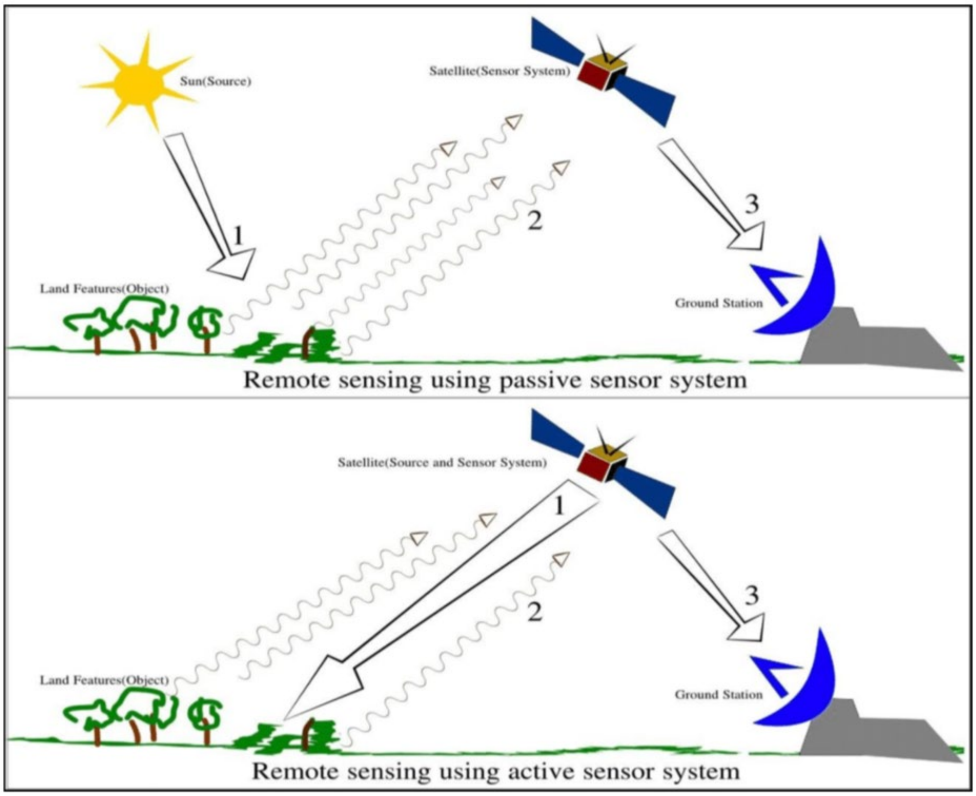


Figure 13.4. The difference between active and passive satellite remote sensing fundamentals. Image courtesy Canadian Space Agency.

Raster data format

Remote sensing systems acquire data as a two-dimensional numerical array or grid, with a single data reading for each location on the ground, called the instantaneous field of view (IFOV). This is the pixel size or spatial resolution of the image. Each square holds a number which represents the amount of energy focused into the satellite's telescope and focused on the detector for a brief fraction of a second. These numbers are recorded and transmitted to the ground where they make up the pictures that we see, but the images are actually grids made up of pixels displayed on our computer monitor (Figure 13.5). These two dimensional raster arrays of numbers are very easily manipulated by our computers, and all of our image processing, discussed below, is done using these grids of numbers.

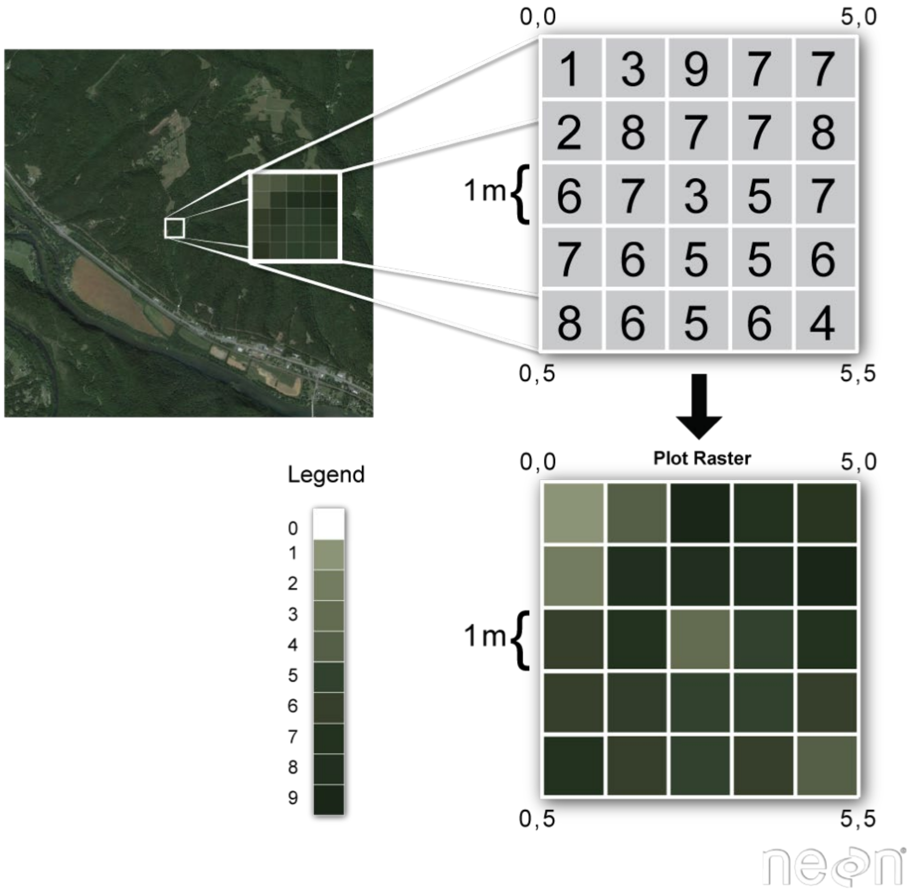


Figure13.5. Raster satellite image format. Image courtesy National Science Foundation's National Ecological Observatory Network (NEON).

Spectral reflectance

A satellite in orbit can identify vegetation types on the ground because different materials on the Earth's surface absorb and reflect energy differently at different wavelengths of the electromagnetic spectrum. Each type of matter (concrete, grass, pine trees, wheat, sea water, etc.) has a unique spectral 'signature' that can be analyzed using remote sensing data based on these identifiable patterns of absorption and reflection (Figure 13.6).

The chart in figure 13.6 shows the spectral reflection patterns of four generalized types of land cover: water, green and dry grass and soil, in the visible, near Infrared (IR) and Mid IR regions of the electromagnetic spectrum. You can see that vegetation looks green in the visible spectrum, because plants absorb a great deal of the blue and red energy for photosynthesis, and reflect back green wavelengths, so that we see grass as green with our eyes. Grass is actually just reflecting the green wavelengths back into our eyes that it does not use for photosynthesis. All physical matter absorbs and reflects energy in different amounts across the spectrum, and we can use our eyes and also our computers to analyze these patterns to identify forests, water, sand, etc. across broad areas, and also to analyze their changes over time with successive imagery acquired on different dates. There have been many civil remote sensing systems, and new ones are becoming available as the technology advances. Today, there are very capable satellite remote sensing datasets that are available without cost, as well as very high resolution imagery, comparable to detailed aerial photographs, that are commercially available for a fee. Modern imagery permits detailed land use and land cover analysis anywhere on the planet for incorporation into our research projects.

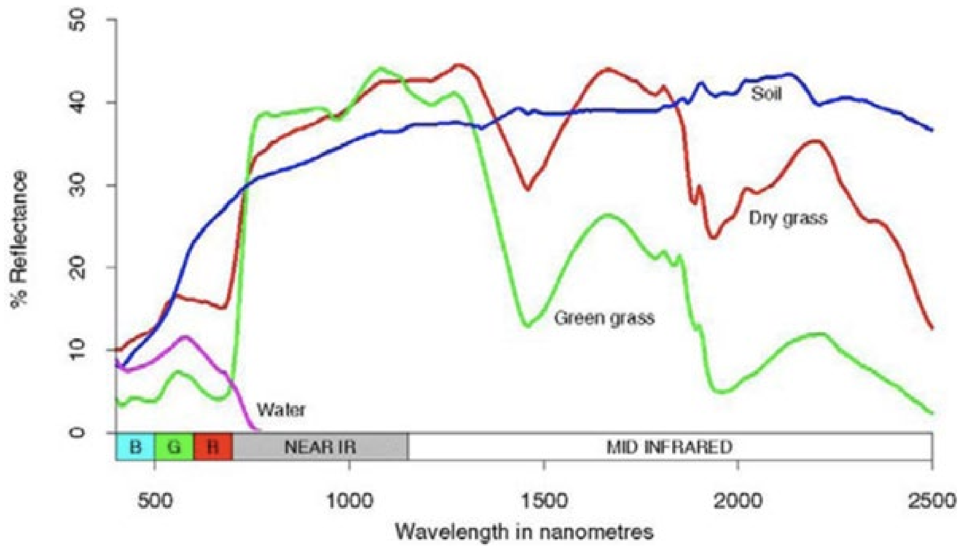


Figure 13.6. spectral response curves of four general types of land cover. The region of the spectrum is along the X axis and the percent reflectance is along the Y axis. Each type of land cover has a unique spectral 'signature', and this allows us to identify features on the ground using remote sensing systems by analyzing the data collected. Image courtesy Canadian Space Agency.

The Four types of Resolutions

Every remote sensing sensor produces data with several parameters that help you decide what data will fit your needs. These are the spatial, spectral, temporal, and radiometric resolutions of the sensor. Spatial resolution means the pixel size on the ground, usually defined as x meters on a side. From an engineering perspective, this is also the Instantaneous Field of View (IFOV) of the sensor. The current Sentinel-2 satellite data has a 10 meter spatial resolution, while Planet Dove satellites have a spatial resolution of ~3 meters. Commercial imagery is available today with a spatial resolution as high as 15 cm (Figure 13.7). Spectral resolution is which areas of the electromagnetic spectrum data were collected. Most sensors have multiple channels that include the visible blue, green, and red, and also near and middle Infrared channels beyond our ability to see, but which are very useful for vegetation and soil analysis. These are called multispectral sensors. Temporal resolution is how often the sensor in orbit will revisit your location (every 16 days for Landsat, every day for Planet), and also the size, or swath width, of the sensor, or how wide an area is collected on each pass (160 km wide for Landsat). Radiometric resolution relates to the radiometric 'depth' of the data, or how finely the reflected energy can be measured. This is measured in bits, such as Landsat 8 and 9's 12 bit data (2^{12}). This means that the sensor can discriminate 4,096 levels of energy responses as recorded at the sensor, and today we have sensors with even higher radiometric resolution. The combination of the four resolution parameters define the capabilities of the system and help us to pick the right satellite data for our needs. All sensors are compromises, and if you get very high spatial resolution, for example, you will get less frequent temporal resolution. Spatial resolution is usually considered first, but all four are important in choosing the right data for your particular project needs.

Figure 13.7. 15 cm spatial resolution true color image detail. Image courtesy Spaceimagingme.com https://spaceimagingme.com/satellite-imagery/15cm-hd-imagery/#iLightbox[d243a88a1d6727af66b]/0

Digital Image Processing

Once the data are collected and transmitted to the ground, they require digital image processing to generate useful images and data. The data are just a stream of numbers that make up a two-dimensional numerical array of numbers, and these must be processed to create the beautiful and useful images of our world that we use. There are many tools available today, including both commercial and Open Source options. Commercial software includes ENVI and ERDAS IMAGINE, among others, and these are excellent tools, but they are quite expensive, difficult to learn and use, and work only in English and in the Windows PC environment. Open Source tools such as GRASS, QGIS, and others are now available without cost, and work on multiple platforms, and are generally easier to learn and use, But all image processing is complex and not to be undertaken lightly or underestimated regarding the time and effort required to generate quality data. The QGIS Semi-Automatic Classification Plugin is an excellent free alternative, and works within the QGIS environment. It provides full image processing abilities, has excellent tutorials, and focuses on free Landsat and Sentinel data, including the process of downloading the data from the web all the way through generating final products: (https://fromgistors.blogspot.com/p/semi-automatic-classification-plugin.html).

Preprocessing

Some of the common preprocessing steps conducted in satellite remote sensing include atmospheric corrections to compensate for clouds and atmospheric haze, georectification to make the imagery accurately fit on a given map coordinate reference system for your GIS, and data corrections (if needed for systematic errors in the data such as dropped scan lines or missing pixels). Once we have our data preprocessed, we can do a variety of useful tasks. These include: edge enhancements, directional filters, data merging of multiple datasets, creation of true and false color composites, and more.

Data Processing

One of the most important types of data processing are the production of thematic classifications. This is where we take the data from multiple bands for each individual pixel and classify these into land use or land cover categories (water, bare soil, urban, forest, and agricultural vegetation, for example). There are two general types of these: supervised and unsupervised classifications. An unsupervised classification is where we let the computer statistically analyze the patterns in the several bands of data and separate these into the various classes as the computer sees fit. A supervised classification is where you, the operator, tell the computer "this small area is water, this is a pine forest", and the computer then analyzes the entire data set and then finds all the pixels that have similar ranges of values and creates a classified map. We often use both, first allowing the computer to sort the data, and then training the computer with known locations for our final analysis. More recently, AI and related Machine Learning tools are also being used to great effect to process large areas of data with high accuracy. Statistical data are generated, as well as images. There are many other processes, including generation of change detection over time of land use and land cover, visualizations and fly-throughs with remote sensing images draped over Digital Elevation Models, and more. The processed data become new raster layers in your project GIS database, and can be analyzed with the other layers derived from many other sources included in the chapters above.

You can often find a participant for your Historical Ecology project with both GIS and remote sensing skills, as they are very much related. If this all sounds too intimidating, you can always pay a commercial provider and include the costs in your grants to receive fully processed remote sensing data that fits your requirements.

In the following section are some examples of the most commonly used such systems that can be used in Historical Ecology research.

Corona declassified spy satellite imagery

The U.S. Corona and follow-on systems were the first satellite spy imagery system for the United States. Begun in the cold war, this super secret film return system was first launched in June, 1959 and operated in various configurations through May, 1972 (Day, Logsden, and Latell 1998). Over 860,000 images were acquired around the world from 1960 to 1972, with a spatial resolution ranging from as low as 2 meters to 100 meters. There are several examples of the use of Corona imagery for archaeological prospection and mapping (Casana 2020) land use mapping (Agapiou 2021), and other applications. These are the oldest available satellite remote sensing systems, and the data have now all been declassified, and are available for download without cost through the USGS portal (https://catalog.data.gov/dataset/corona-satellite-photography). The data were mostly acquired over the former Soviet Union and China, but data exist over much of the world (Figure 13.8).

Free and Open Source data

Today, we are fortunate to have two excellent sources of global passive satellite imagery that are freely available. The U.S. Landsat program and the European Space Agency Sentinel 2 program. Landsat began in 1972 and is the longest running such program. Today, Landsat 8 and 9 are collecting data daily, and the entire imagery archive is searchable and available for free online from the USGS (Figure 13.9). While new systems continue to be developed as technologies improve, the goal has always been to allow change detection between newer and older data.

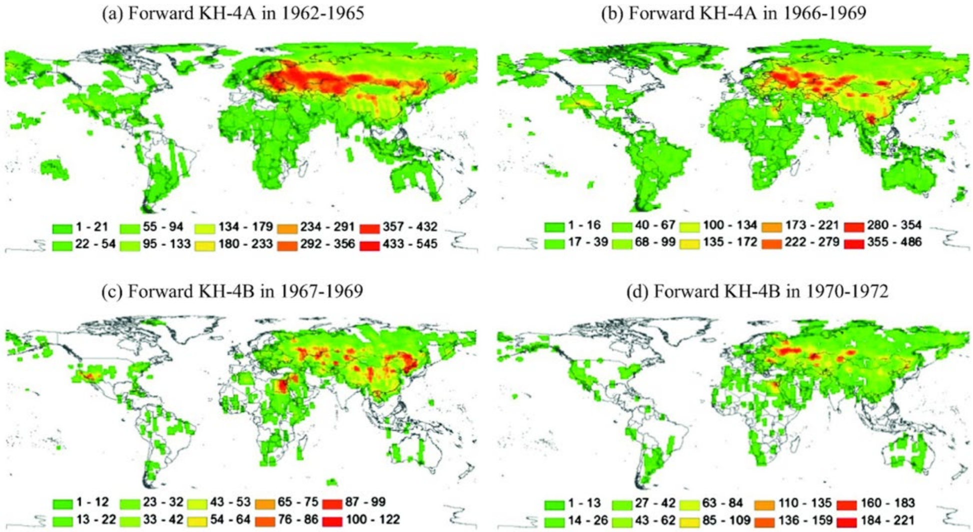


Figure 13.8. The area covered by the Corona KH-4A and 4B satellites. (*Source:* https://lta.cr.usgs.gov/declass_1). The different colors indicate the number of images acquired over each area. White indicates no imagery available.

Figure 13.9. The Landsat 9 satellite in orbit. Image courtesy NOAA.

The Landsat program has continued uninterrupted, and the most recent Landsat 9 was launched on September 27, 2021, continuing some 50 years of continuous data collection and free data distribution (Masek et al. 2020).

Shown in figure 13.10 are the various Landsat spectral bands over time. Landsat 9 is at the top. Landsat 8 and 9 measure different ranges of frequencies along the electromagnetic spectrum – you can think of each as a 'color', although not necessarily a color visible to the human eye. Each range is called a band, and Landsat 8 has 11 bands. Landsat numbers its blue, green, and red sensors as bands 2, 3, and 4, so when we combine them we get a true-color image, where blue water on the surface appears blue and green forests appear green.

The European Sentinel satellite series is part of the larger Copernicus program (Figure 13.11). The Copernicus program and U.S. Landsat today offer freely available high resolution multispectral imagery, downloadable from the internet. There are also several commercial vendors who operate and sell ultra high resolution imagery with pixels as small as 15 cm on a side, equal to aerial imagery, but these are quite expensive and are often not affordable for historical ecology projects. The operational combination of Landsat 8 and 9 and Sentinel 2 provides 2 or 3 day revisit rates for the entire Earth.

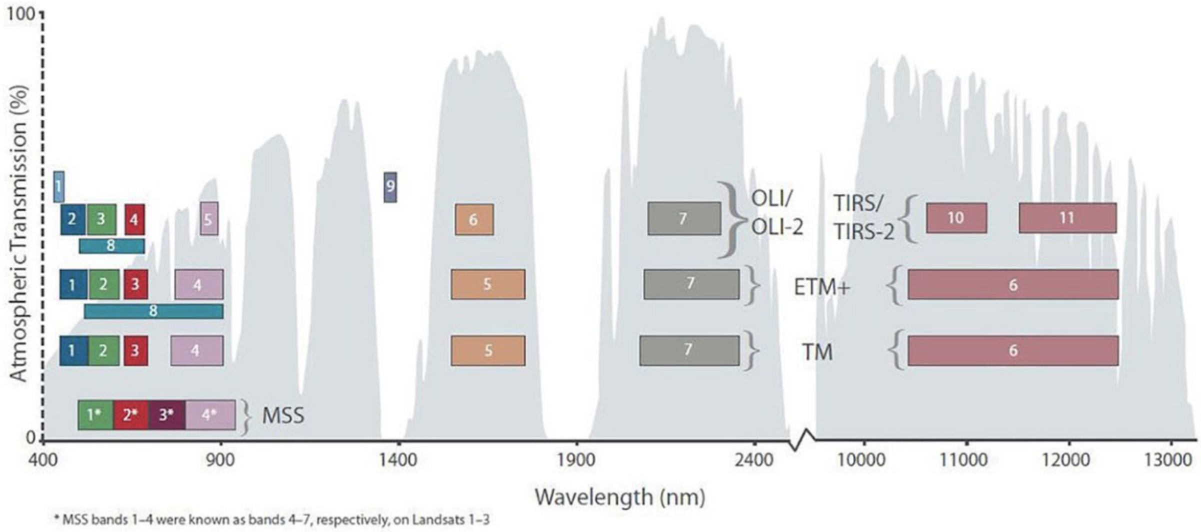


Figure 13.10. Landsat 8 and 9 imager spectral wavelengths are shown on the top, with the slightly different Landsat 7 instrument and older MSS shown below. Gray areas show where the Earth's atmosphere is transparent, so we can conduct space remote sensing in these parts of the spectrum. In the other regions, the atmosphere absorbs the energy and so no remote sensing is possible in those regions of the spectrum.

https://directory.eoportal.org/web/eoportal/satellite-missions/l/landsat-8-ldcm

All Copernicus data are free and available over the internet. At the time of this writing, there are two Sentinel-2 optical satellites (A and B), launched in April 2015 and July 2016 (Figure 11). https://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/sentinel-2a/

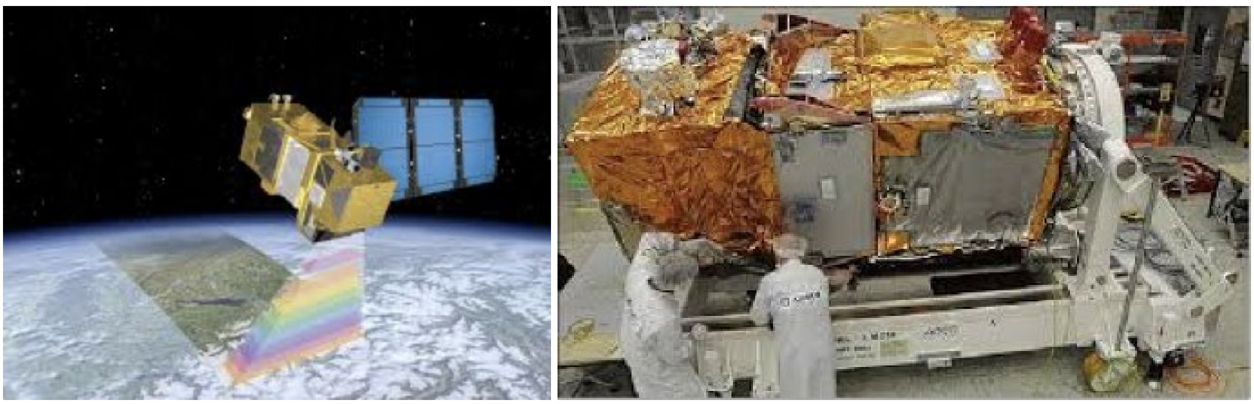


Figure 13.11. The Copernicus program (formerly GMES) is a partnership of the European Community and the European Space Agency, and consists of several satellite designs, and includes Radar, high resolution optical, Geostationary, Lidar, ocean and climate data systems. Image courtesy ESA
http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus

Sentinel-2 spectral wavelengths

Sentinel-2 has 13 spectral bands, with spatial resolution of 10, 20 and 60 meters, and a temporal resolution (revisit rate) of 5 days. You can learn more about the satellites and ground systems at: https://directory.eoportal.org/web/eoportal/satellite-missions/c-missions/copernicus-sentinel-2

In figure 13.12 are the Sentinel-2 spectral bands, shown at the top, along with those of Landsat 7 and 8. You can see that the Sentinel-2 bands are very similar to Landsat, with the exception that Sentinel-2 has no thermal bands (at right). Gray areas show where the Earth's atmosphere is transparent, so we can conduct space remote sensing. In the other regions, the atmosphere absorbs the energy and no energy reaches the ground. https://directory.eoportal.org/web/eoportal/satellite-missions/c-missions/copernicus-sentinel-2

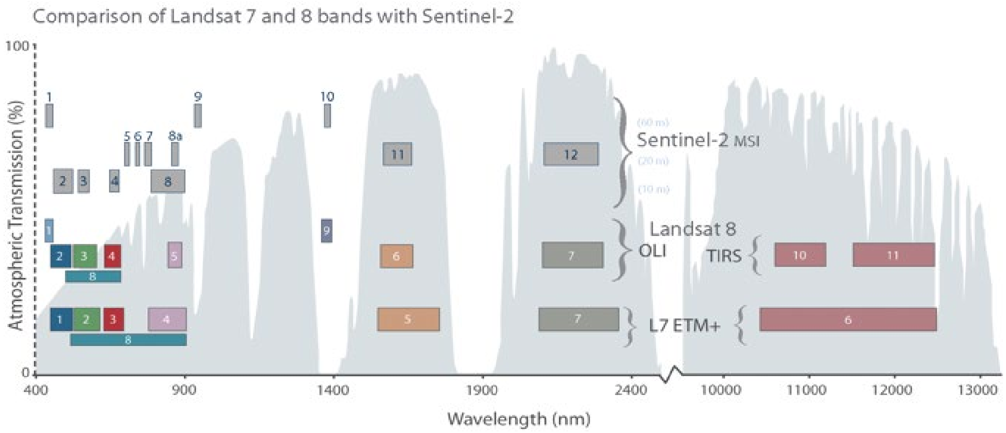


Figure 13.12. The spectral bands of Landsat 7, Landsat 8, and Sentinel 2.

The Sentinel-2 Multispectral Imagery (MSI) has a swath width of 290 km and spatial resolution of 10m (four visible and near IR bands), 20 m (six red edge and shortwave IR bands), and 60 m (three atmospheric correction bands). Sentinel-2 data are delivered in 'tiles' of 100x100 km areas, and 'granules' of 25x23km subzones. This Sentinel 2 image of our Burgundy research area, was acquired on October 20, 2018 and is shown in figures 13.13, 13.14, and 13.15. It was acquired online and was processed using a combination of both ArcGIS and QGIS.

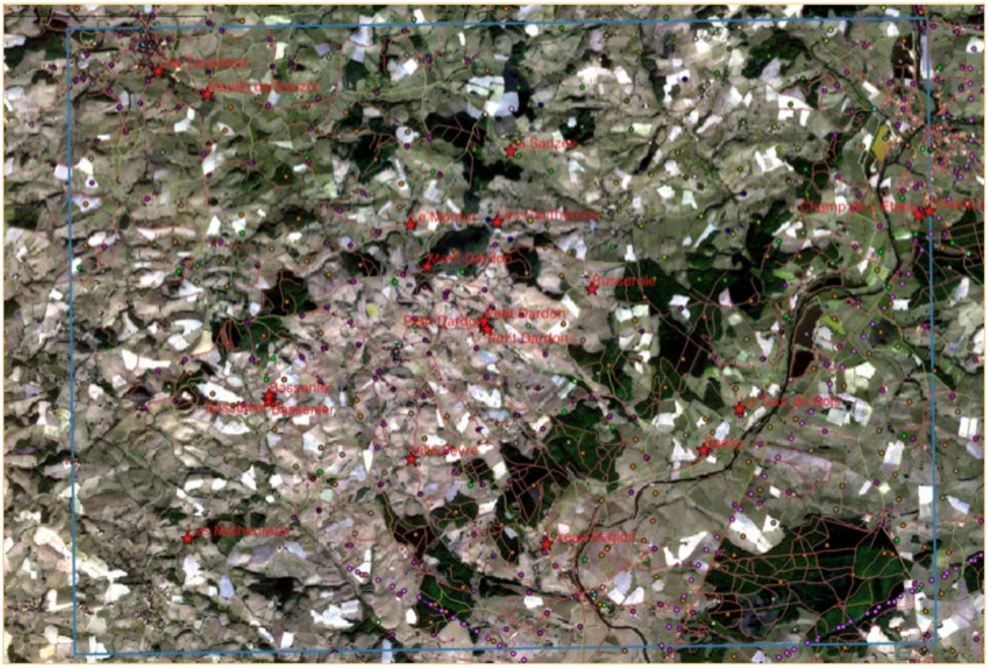


Figure 13.13. European Space Agency Sentinel 10 meter true color image acquired 2018.10.20. This image shows the land use and land cover of our study area (outlined in blue), and individual features are identified in red in our GIS. Image processed by Ducan Amderson, QGIS image by Scott Madry.

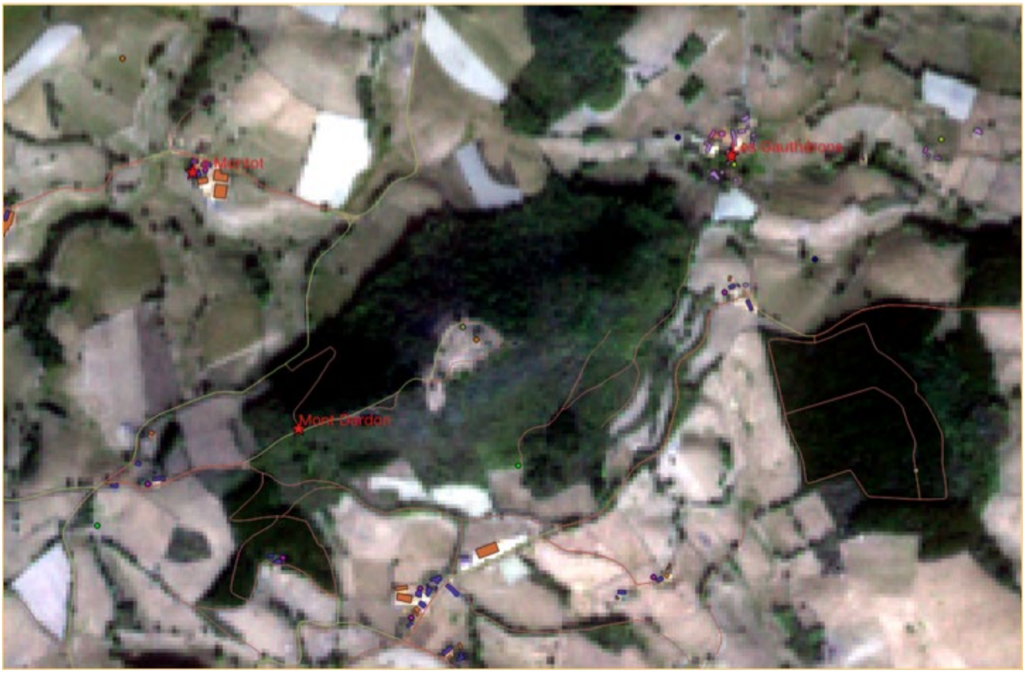


Figure 13.14. Sentinel-2 10 meter image acquired 2018-10-20. This is a Detailed image of Mont Dardon with Mont Dardou at right. This is a true color image, so green are forested areas, and various field are shades of brown. Individual houses and structures in our GIS are displayed in orange. Image processed by Ducan Anderson, QGIS image by Scott Madry.

Figure 13.15. A digital aerial image of Mont Dardon for comparison. Image courtesy IGN Geoportail. https://www.geoportail.gouv.fr/carte

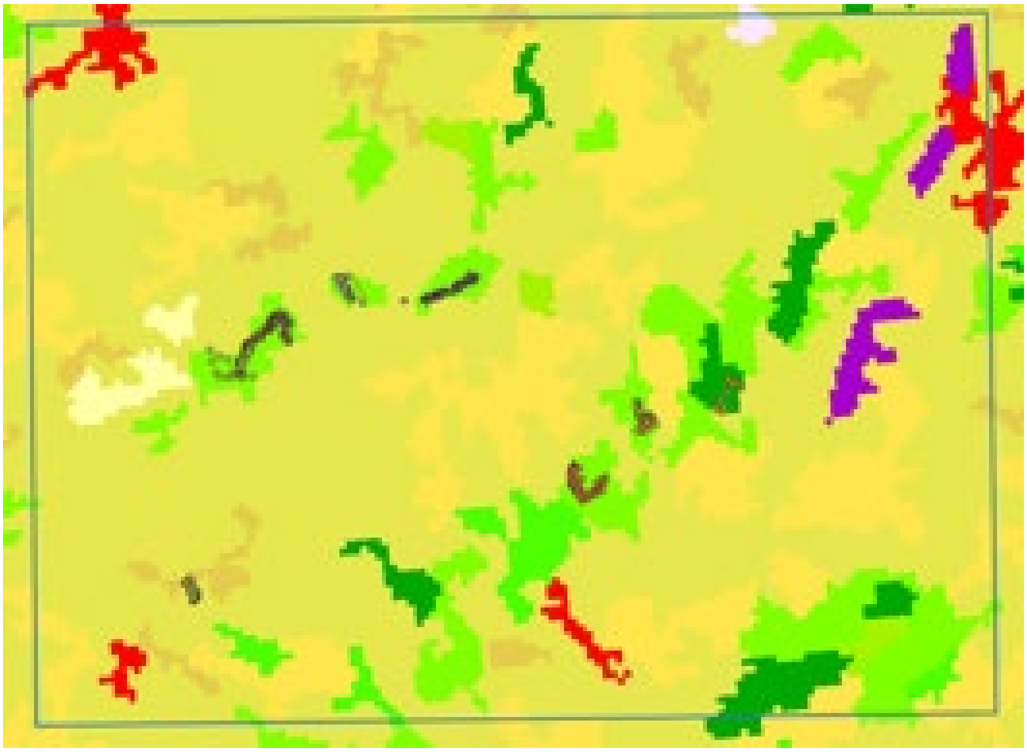


Figure 13.16. 2018 Sentinel image at top, with land use/land cover classification at bottom. Hardwood forest zones are in light green, pine forests are dark green, farm fields are in yellows. QGIS image by Scott Madry, image processing by Duncan Anderson.

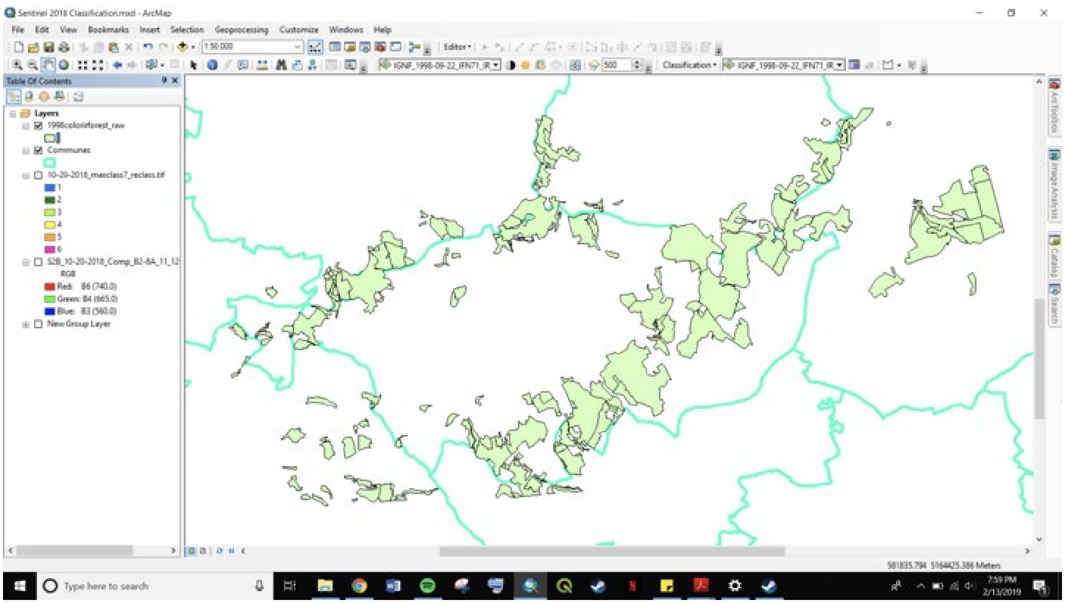


Figure 13.17. 2018 Sentinel-derived forest cover of the study area. Image processing by Duncan Anderson. QGIS image by Scott Madry.

Planet

The largest commercial satellite imagery constellation today is operated by Planet of San Francisco, USA (https://www.planet.com). A small Silicon Valley start-up just a few years ago, Planet now operates the world's largest constellation of remote sensing satellites, over 200, and images the entire Earth's surface, over 300 million sq. km., every day with imagery of very high spatial resolution (~3.7 meters). The data are commercially available and are acquired using tiny "3-U" satellites called doves, as shown in figure 13.18.

What does this have to do with Historical Ecology?

Remote sensing satellites and the digital image processing of the data derived from them have important benefits for Historical Ecology research, primarily for the determination of land use and land cover classifications and their changes over time, which are key parameters in Historical Ecology research. There is a growing number of examples of projects who are using such data (Herrault & David. 2022), and this will only increase in the future. There are many very capable Open Source satellites, datasets, and image processing software available today, from the U.S. Landsat series and European Sentinel systems that acquire moderate to high resolution data (10-30 meter pixels) that can be acquired and processed without cost into vegetation, agriculture, water quality, and other products. These are very useful for regional analysis, but they cannot (yet) be used for individual, very large scale vegetation analyses, such as within a single field or hedgerow, for example, this still requires detailed field analysis by trained biologists. Using detailed field ecological collection provides us with 'ground truth' that informs and improves our satellite imagery, and extends the reach of these small surveyed areas. We often engage in nested surveys, where small areas are investigated in detail on the ground and then extrapolated out to larger areas using aerial or satellite imagery. The technology continues to advance rapidly, and there are commercial satellites today that image the entire Earth every day, some with a pixel size of only 15 cm.

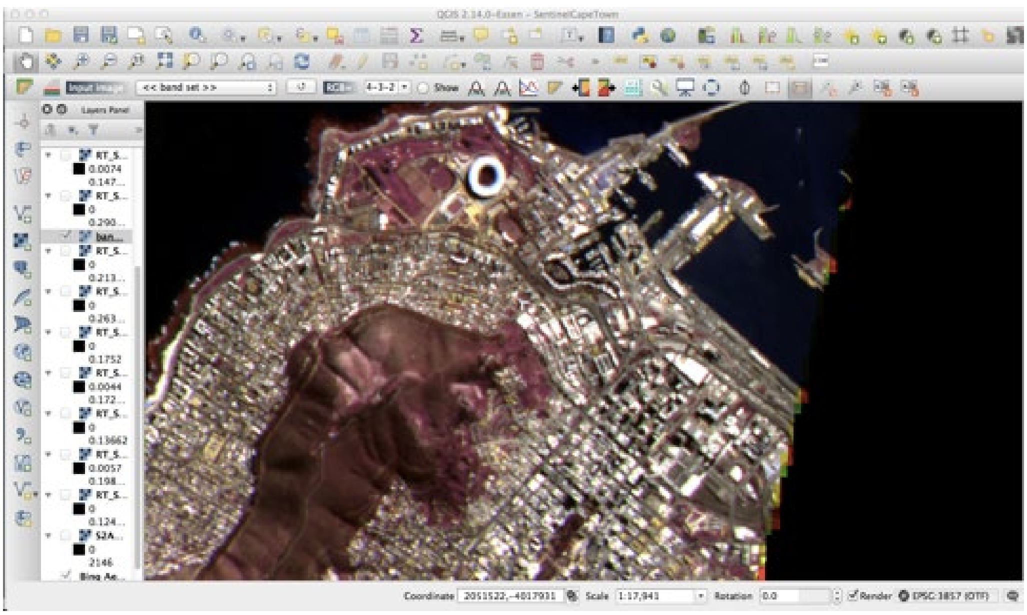


Figure 13.18a and 24b. Two high resolution images of Cape Town, South Africa, acquired by Planet satellites. The top image is in the visible spectrum, and the lower is in the color Infrared. The port complex is at upper right, and Cape Town stadium is in Green Park at the top. Urban areas with individual buildings surround the 'Lion's Head' mountain at center, which is covered in forest. Large areas of burn scars are visible on the mountain as lighter pink areas. Images courtesy Planet. QGIS image by Scott Madry.

Figure 13.19. Planet cofounder Will Marshall holding one of the tiny Dove remote sensing satellites.

These are very useful for vegetation and ecological monitoring over large areas, particularly in remote locations that are not easily accessed, or if quick coverage is needed due to significant events such as damaging weather or forest disease or other infestations. They are very useful in monitoring remote areas for illegal logging, development, and the looting of archaeological sites. The images and classified maps, as well as other derived products such as digital elevation models, thermal maps, and more, can then be easily entered into GIS systems for further analysis of vegetation communities and ecosystems with the data derived from other sources.

Conclusions

Today, there are multiple freely available datasets of satellite imagery, all available to researchers free of cost via internet download. Other commercial data are also available for a fee, including data with pixels of only 15 cm, equal to the highest quality aerial photography. The archives of civil remote sensing data reach back to 1960 and the early 1970's. Each of these datasets have different and useful characteristics, and there is an important benefit in acquiring and analyzing different types of data over different seasons and years. This is referred to as the 'multi' concept. There are also, and equally importantly, Free and Open Source Software (FOSS) image processing and analysis tools to process these data and integrate the results into your GIS environment. Free imagery can now be acquired anywhere in the world on a weekly or monthly basis, allowing for frequently updated forestry, agricultural, land use, flooding, and other analysis over time. Unlike in the past, there are now no practical barriers of spatial resolution or cost to including these data into your regional research activities.

Data Sources and Resources

There are several excellent basic remote sensing books available, here is a freely available one from ITC in the Netherlands: (https://webapps.itc.utwente.nl/librarywww/papers_2009/general/principlesremotesensing.pdf. Many universities offer hands-on classes and remote learning courses as well.

QGIS Open Source satellite remote sensing analysis code and tutorials
https://fromgistors.blogspot.com
https://fromgistors.blogspot.com/2018/02/basic-tutorial-1.html

Sources of Satellite Remote Sensing Imagery

IGN French geodata site https://www.ign.fr
The IGN Geoportail https://www.geoportail.gouv.fr

Historical Corona satellite Imagery https://www.usgs.gov/centers/eros/science/usgs-eros-archive-declassified-data-declassified-satellite-imagery-1?qt-science_center_objects=0#qt-science_center_objects

NOAA Land Processes Distributed Active Archive Center https://lpdaac.usgs.gov

You can download all global archived Landsat data free at: http://landsat.usgs.gov/Landsat_Search_and_Download.php

USGS Landsat 8 website

Landsat download sites

NASA Goddard Remote Sensing Tutorial

Japanese ASTER data https://earthdata.nasa.gov/learn/articles/japan-nasa-provide-open-access-to-aster-data

Archaeology uses of Sentinel 2 data

https://www.researchgate.net/publication/322937167_Identification_of_Leveled_Archeological_Mounds_Hoyuk_in_the_Alluvial_Plain_of_the_Ceyhan_River_Southern_Turkey_by_Satellite_Remote-Sensing_Analyses/figures?lo=1
https://www.mdpi.com/2072-4292/6/3/2176

https://www.mdpi.com/2076-3263/9/1/25/htm

https://www.tandfonline.com/doi/pdf/10.1080/00934690.2019.1629256

https://ktisis.cut.ac.cy/handle/10488/8607

https://ktisis.cut.ac.cy/bitstream/10488/8607/1/remotesensing-06-02176.pdf

The EU/ESA Copernicus Satellite Program https://www.copernicus.eu/en

Sentinel-2 program

Sentinel-2 data hub

Sentinel-2 User Guide

Planet satellite data https://www.planet.com

References

Agapiou, A. 2021. Land Cover Mapping from Colorized CORONA Archived Greyscale Satellite Data and Feature Extraction Classification. *Land* 2021,*10*,771. https://doi.org/ 10.3390/land10080771

Casana, Jesse 2020. Global-Scale Archaeological Prospection using CORONA Satellite Imagery: Automated, Crowd-Sourced, and Expert-led Approaches, Journal of Field Archaeology, 45:sup1, S89-S100, DOI: 10.1080/00934690.2020.1713285

Day, Dwayne A.; Logsdon, John M.; Latell, Brian 1998. Eye in the Sky: The Story of the Corona Spy Satellites. Washington and London: Smithsonian Institution Press. ISBN 1-56098-830-4. OCLC 36783934.

Goddard, George: 1969. Overview. Doubleday, New York

Herrault, Pierre-Alexis & Sheeren, David. 2022. Remote Sensing for Historical Ecology. 10.1002/9781394169764.ch6.

Madry, S. 2008. Des gorilles du Rwanda aux sites archéologiques de la vallée de l'Arroux, Introduction aux nouveaux outiles de cartographie et d'analyse spatiale". in: "La Cartographie au Service de la Recherche et de l'Aménagement du Territoire", Centre Archéologique Européen, Glux-en-Glenne, France.

Madry, S. 2007. An Evaluation of Google Earth for Archaeological Exploration and Survey, in: Clark, J.T. and E.M. Hagemeister (eds.) Digital Discovery. Exploring New Frontiers in Human Heritage. CAA2006. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 34th Conference, Fargo, United States, April 2006. Archaeolingua, Budapest, pp. CD-ROM 329-337.

Madry, S. 2005. Archaeological Applications of Remote Sensing. In: *Remote Sensing for GIS Managers*, Stan Aronoff, ed. ESRI Press. Redlands, California.

Madry, S. 1991. Un Emploe des Systemes de Teledetection et d'information Geographique dans une Analyse Regionale de Repartition Spatiales Archaeologiques, In: Archeologues et Ordinateurs, Lettres d'Information du Centre de Recherches Archeologiques. 17:1-11. Paris: Centre Nationale de la Recherche Scientifique.

Madry, S. 1990. An Application of Remote Sensing and GIS in a Regional Archaeological Survey (with Carole L. Crumley) in Interpreting Space: GIS and Archaeology, K. Allen, S. Green, and E. Zubrow, eds. Taylor & Francis, London.

Madry, S. 1987. Remote Sensing in a Temperate Regional Archaeological Survey in France, in Regional Dynamics: Southern Burgundy from the Iron Age to the Present, edited by C. L. Crumley and W. H. Marquardt-published by Academic Press.

Madry, S. 1983. Remote Sensing in Archaeology." Archaeology Magazine, May-June, l983 (pp. l8-l9).

Masek, Jeffrey G. Michael A. Wulder, Brian Markham, Joel McCorkel, Christopher J. Crawford, James Storey, Del T. Jenstrom, 2020. Landsat 9: Empowering open science and applications through continuity, Remote Sensing of Environment, Volume 248.

Pelton, J., Madry, S., and Camacho-Lara, S. (Eds.). 2012. Handbook of Satellite Applications, Springer, New York, Frankfurt, and London. (Executive co-editor). First edition, 2-volume, 1,226 page reference work.

Pelton, J. Madry, S. and Camacho-Lara, S. (Eds.). 2017. Handbook of Satellite Applications, second edition New York; Heidelberg-Dordrecht; London: Springer. Two volumes, 1,556 pages.

Scollar, I. A. Tabbagh, A. Hesse & I. Herzog 1990. Archaeological prospecting and remote sensing. [Topics in remote sensing 2.] xviii 1990. Cambridge & New York: Cambridge University Press; ISBN 0-521-32050-X

Staerck, Chris (ed.): 1988 Allied Photo Reconnaissance of WWII. PRC, London

Stancioff, C, R. Pontius, S. Madry, E. Jones 2015. Historic Forest Change: New Approaches to Land Use Land Cover" Pp. 65-71, Proceedings of the 42nd Annual Conference on Computer Applications and Quantitative Methods in Archaeology CAA 2014- 21sh Century Archaeology. F. Gilligny, F. Djindjian, L. Costa, P Moscati and S. Robert, eds. Archaeopress, Oxford, UK.

CHAPTER 14

SATELLITE POSITION, NAVIGATION, AND TIMING (PNT) AND SYSTEMS FOR FIELD DATA COLLECTION

SCOTT MADRY

Figure 14.1. The Earth, surrounded by the GPS satellite constellation (image courtesy NOAA) and an Applic iPhone running the MotionX GPS app with background satellite image in the field. Photo: Scott Madry.

This chapter will introduce the methods, techniques, and approaches of satellite PNT (Position, Navigation and Timing) systems and their use in field data collection in support of Historical Ecology research. Several similar PNT systems currently exist, which allow for the recording of our precise location on the surface of the Earth, navigation on the land and water, and precise timing services. PNT systems, also referred to as Global Navigation Satellite Systems (GNSS), include the original US Global Positioning System (GPS), and the later Russian Glonass, Chinese Beidou, Indian GAGAN, and European Galileo systems. There will likely be more such systems in the future. These broadcast free and open signals that can be received by low-cost hand-held receivers, including smartphones and dedicated field data loggers. PNT receivers vary widely in cost and precision, but centimetric measurements and accurate timing can generally be collected in the field in real time. This is obviously useful in Historical Ecology projects, as these integrate accurate spatial and timing data collected in the field, along with geotagged ground photos and various attribute data collected, with other data in our project GIS systems for use by all participants in the project. This chapter will discuss the basic technology, how it works, how it can be used, and some of the common methods of using satellite position data as well as some limitations of the technologies. Some comparison of the currently available commercial and Open Source field data collection systems will be presented, and examples will be shown of field data collected using PNT receivers. The chapter will present some examples from our own work, including our long-term research in Burgundy, France and a mountain gorilla conservation project in East Africa.

Introduction

Satellite-based PNT has now become an invisible part of our daily lives, a hidden infrastructure that is involved in many aspects of our global transportation, energy, and routine activities (Madry 2015, 2024). Even the internet, electrical power grids, and stock market trades are timed using GPS timing services. The disciplinary underpinnings and perspectives of PNT include geodesy, space sciences, satellite applications, geography, and any of the many individual disciplines that use these tools.

GPS and the other, similar international systems, all rely on a constellation of satellites in a medium orbit (~20,200 km) that constantly broadcast coded signals which are timed by several atomic clocks onboard each satellite (Teunissen and Montenbruck 2017). A complex ground control infrastructure monitors the system, and ensures accurate timing signals are updated frequently, and check for errors. Using an inexpensive receiver on the ground, including every smartphone sold today, one can map and track their location and time anywhere on or above the planet, including in fast-moving ships and aircraft. The signals are broadcast in the clear and are available world-wide without cost to the end user. Military versions of these systems also exist that have limited access and improved performance.

Many dedicated GPS receivers are available for a range of costs and levels of precision. These are often separated into three general categories: recreational, mapping, and survey grade systems, with different levels of cost and precision for each, as described below. Your smartphone (recreational) can give you perhaps 30-50 meters precision on the ground, while an inexpensive dedicated GPS receiver (mapping) can provide ~5-10 meters precision for around US$100. Real Time Differential GPS (survey), available in many GPS receivers, can provide between 0.5 and 2 meters in real time using a reference receiver that broadcasts local corrections. Satellite Based Augmentation Systems (SBAS) have been developed that use a network of ground stations to measure errors in the signals and then broadcast every few seconds a correction signal to GPS units equipped to receive this, providing ~2 meter precision. Several such systems exist, including the original U.S. operated Wide Area Augmentation System (WAAS) which covers North America (Figure 14.2). The European-operating system called EGNOS covers Europe, the Indian GAGAN covers the Indian Ocean area, and the Japanese MSAS system covers Japan. China and Russia also operate similar systems, but these are closely controlled and are not publicly available. All of South America, Africa, and much of Asia and the Middle East are not currently covered (Figure 14.2), but there are also commercial systems available for a fee, such as OmniSTAR, which are available globally using custom-built receivers.

The high end PNT systems are called Carrier Phase Tracking systems, or RTK, for Real Time Kinematic receivers, and these process the location data in a different way. This requires a professional grade receiver and also a fixed base station, and can provide centimetric precision (~15cm), with a price range from around US$1,500 to several thousands. This is much less expensive than just a few years ago. These systems can also be rented. Post processing of your field data is also possible, increasing the precision in the lab after you download and post-process your data using stored correction information. These services are available around the world, and are generally available for free in many developed nations. So with PNT and GPS, you generally do get what you pay for, and cost generally equals precision, although the price of all systems continues to decline over time. It all depends on what you are measuring and how precise you need to be to address the questions at hand. But your location anywhere in the world can routinely be mapped to within your arms length using a receiver costing around US$100.

PNT systems data (and related geotagged photos) can easily be directly integrated with your project GIS system as either vector points, lines, or polygons, as well having a date and time stamp attached, all depending on how you collected the data in the field or do your post processing. All current GIS systems, both proprietary and Open Source, can input the most commonly used PNT receiver formats directly and can convert the data into standard vector GIS formats for storage and integration with your GIS data.

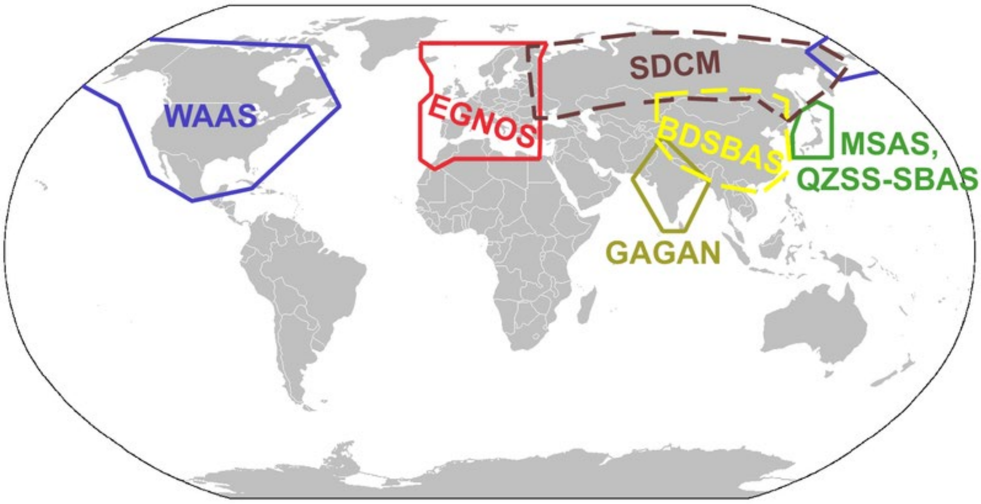


Figure 14.2. Space Based Augmentation Systems service areas. Image courtesy wikimedia.
https://commons.wikimedia.org/wiki/File:SBAS_Service_Areas.png

PNT Field Data Loggers

Today, there are several, dedicated GPS-based field data loggers that allow you to enter database attribute information and collect geotagged photos in the field when you collect your field data. ESRI, the developers of the commercial GIS system ArcGIS, offers ArcGIS Field Maps, which replaced their similar ArcPAD product in 2020. ArcGIS Field Maps is a mobile field data application that allows field data collection using a smartphone or tablet. You can create a map in ArcGIS, download it to your tablets, and then collect data in the field. Some of our Swedish colleagues work with ArcGIS online and it is in direct contact with Field Maps. They can simultaneously upload data in real time so that multiple people in the field and lab can see the points and polygons collected as soon as they are synched, as long as they are in wireless internet contact. These data are then uploaded and synched at the end of the day in the cloud. You can collect GPS data, add field photos or videos, and add attribute data and field observations, and you can send data back live if you have a working wireless or bluetooth connection in the field, or store it for upload later. One limitation is that these data can only be used within the ArcGIS family of systems. https://www.esri.com/en-us/arcgis/products/arcgis-field-maps/overview

There are several excellent Open Source field data collection alternatives as well, including QField (https://qfield.org). This allows you to conduct field work and collect ground photos, videos, and field observations and seamlessly integrate these into the Open Source QGIS using the free QField sync plugin of the popular and free QGIS (Figure 14.3).

Figure 14.3. The QField user interface on a smartphone. Image courtesy QField.
https://www.opengis.ch/2021/02/24/powerful-and-gentle-qfield-1-8-selma-sneaked-in/

Another QGIS-related field data collection system is Input, developed by Lutra Consulting in the UK. This is a Free and Open Source app that works on both Android and IOS devices, and allows you to use your smartphone or a tablet to collect field data as points, lines, or polygons and collect geotagged photos, and then seamlessly upload these to your QGIS database. It allows you to sync data from multiple field devices and also works offline in the field if you are out of range of wireless internet (https://inputapp.io/en/, Figure 14.4).

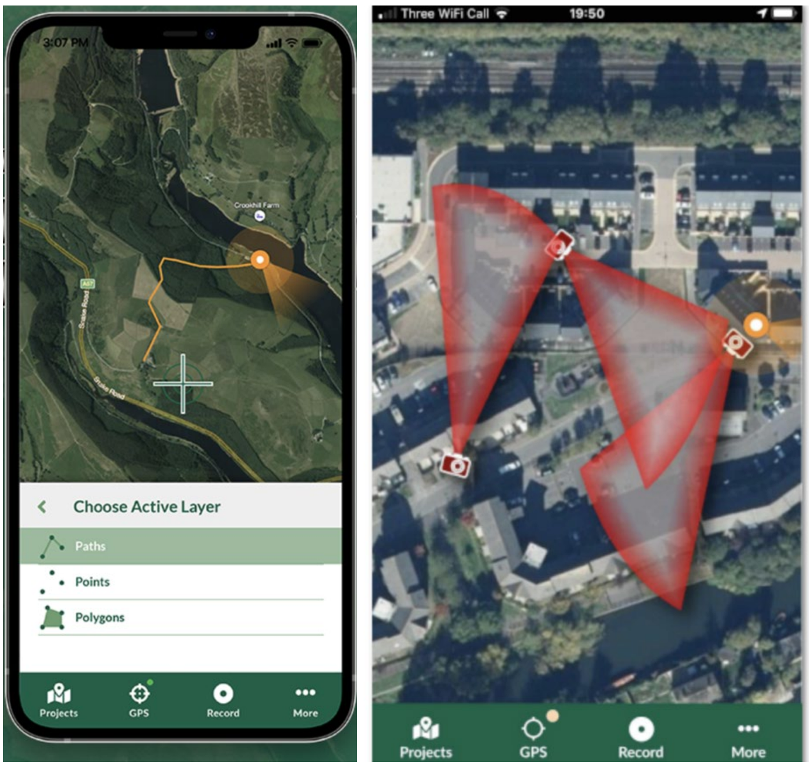


Figure 14.4. Input data collection screen and geotagged photos at right. The photo at right indicates three locations where geotagged photos were taken and the direction the camera was pointing. Courtesy Lutra Consulting.

A simpler, analog approach is used by Field Papers (http://fieldpapers.org/about) which is an online program that lets users define a study area and print out a paper Atlas of OpenStreetMap map tiles covering that area at a desired size and scale. Notes and markings on the maps made in the field can be photographed and uploaded, in what is called a snapshot, and these are automatically connected online with the original maps for later visual analysis or printing. It does not use any GIS or GPS, and is strictly an analog map system, which may be useful in situations where training limitations or access to PNT systems is not feasible.

Field data collection and the design and management of field survey activities varies widely by discipline and purpose. Archaeological field surveys are structured and conducted very differently from geological, ecological, or forestry field activities, so your field operations should be grounded in the best practices of your particular discipline. One benefit is that, if conducted using PNT systems, the field activities of any disciplinary project design can also be useful more broadly across an interdisciplinary project. Collecting geotagged ground photos is a good example, where different researchers from many disciplines often see many different things in the same image. Careful planning, field design, data collection, and data archiving are all important aspects of successful field activities, and are addressed below. In a Historical Ecology project, it might be beneficial for researchers from different disciplines to coordinate field data collection forms before the fieldwork commences, so that the maximum data can be collected by all groups. For an interesting example of how the American Red Cross approaches using untrained volunteers to conduct post-disaster GPS field data collection, see: https://americanredcross.github.io/Guides/gisfieldwork/pdf/Guide_to_GIS_Fieldwork_v1.1.pdf

Fig 14.5. A color 1834 cadastral map displayed on one of our Garmin GPS units in the field. Photo: Scott Madry.

In figure 14.5, we are standing in the track of an old, now disused road, visible as the sunken, green area at the right of the photo. In the GPS display, our position in the small blue triangle at center (difficult to see), shows my position along the track of the old road, as shown in our georeferenced, 1834 historical map on the screen. The mill and mill pond of Chevalot-du-Bas is visible on the GPS display and in the background at upper left, This ability to pick different historical maps to display in real time while in the field is a powerful capability, and was used extensively for our analysis of water, mills, and ponds in the study area (Madry et al. 2015).

One example of this work was at the old mill site of Noirterre which, according to our historical maps and records, was destroyed when the dam failed during a severe storm sometime between 1840 and 1848. We knew that the mill structure was completely destroyed, but had not been able to locate it in the field. Using this technique, we were able to navigate to the location of the mill as it was indicated on our detailed cadastral maps (Figure 14.6 and 14.7), and then displayed on our GPS and we located large foundation stones of the structure, and accurately collected its coordinates for our GIS database, including geotagged field photos.

Figure 14.6. Left: The detailed 1838 map of the dam and mill complex at Noirterre that was downloaded into our Garmin GPS. In the right figure we were standing under the ‘r’ in Noirterre in the map, looking to the right across the old dam. The breached dam at Noirterre in the background. A paper copy of the 1838 historical map is at right, which is also visible in our Garmin GPS unit. Photo: Scott Madry.

QGIS ground photo geotagging

Once field data are collected, including ground photos and completed field forms, these data can be integrated into our project GIS. The Event Visualization Tool, or eVis, was a powerful capability in QGIS, that allowed you to geo-tag ground photos and associated field-collected GPS location and tabular data, and enter them into your GIS as a vector point file (https://biodiversityinformatics.amnh.org/open_source/evis/index.html), as shown in figure 14.7. In the example shown in Figure 14.7, the vector GPS points are shown on the QGIS screen at left as red dots overlaid on our scanned 1:25,000 IGN topo map. When the eVis plugin is activated in QGIS, and when you click on a red point on the map, in this case the top red dot by the top blue pond, it will open a new window (at right) showing you the ground photo, along with the associated text data that was collected in the field, which is shown at top right. In this case, it shows a pond that had been recently drained for maintenance and the collection and sale of the fish. When you click on a point on the GIS map (red dots), an arrow appears, indicating the compass direction in which the ground photo was acquired.

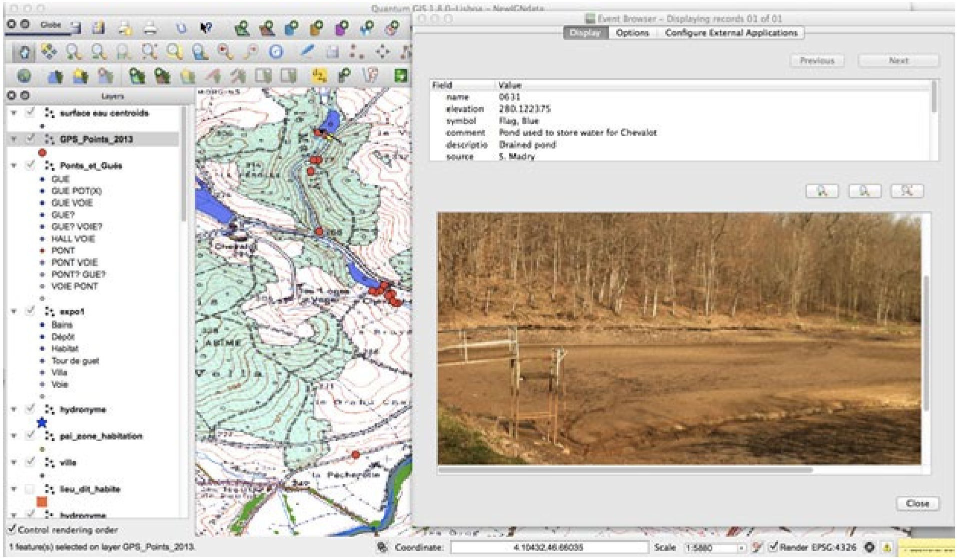


Figure 14.7. A view of some of our eVis data field data. At left is the GIS database, showing the modern 1:25,000 IGN topo map with the location of geotagged photos shown in red.

N.B. eVis has been superseded by new QGIS capabilities in 2020 and is no longer a part of QGIS, but the same capabilities have been incorporated directly into QGIS as a part of the newly updated version. This is frequently done, useful external capabilities are incorporated directly into the core system. All you have to do is go to 'Import Geotagged Photos' in the Processing Toolbox and it is done, very simple. This creates a new vector point layer for each photo derived from the JPEG images in a folder. The point layer will contain a single point for each photo. The altitude data will be automatically read as the Z value, and the coordinates, time taken, and direction are all saved in your attribute table. Non-geotagged photos can also be downloaded and manually geolocated, if necessary, but almost all modern smartphones can collect geotagged pics if you enable the location feature.

QGIS field use, 1 to 1 field digitizing

QGIS also has a very useful capability to collect vector GIS point, line, and polygon data directly in the field using a laptop and GPS. The QGIS GPS module, allows you to download and upload GPS data to and from virtually any receiver or data format. It also has a function that, when a GPS device is attached to your laptop or vehicle, you can turn on the digitizing capability in the Editing menu, and you can actually collect 1 to 1 vector point, line, or polygon data from a vehicle, aircraft, or on foot, with the simultaneous full use of QGIS to zoom, roam, and display other data. You are simply conducting 1 to 1 digitizing in the field. This has many uses. For example, in the old days when we were flying for aerial archaeology prospection, it was very difficult to actually locate the individual field containing a potential site of interest back on the ground after the flight. Marking on a map was inaccurate at best, and finding that spot on the ground was even harder. Today, with GPS, one can track the exact location of the aircraft and view our geotagged aerial photos and GIS data at the same time, including turning off and on various historical maps and aerial photos, all shown on our laptop in the cockpit. On the ground, you can track your location in a vehicle across open ground, and can walk the extent of located ground features, all entered directly into QGIS as vector point, line or polygon features, complete with attributes and geotagged ground photos.

MotionX iPhone app

Even at their lower prices today, not everyone can purchase or have access to dedicated GPS receivers, but virtually everyone today has a smartphone, and all of these include GPS (and Russian Glonass or other) PNT receivers. While these are somewhat less precise in position than dedicated GPS receivers such as those from Garmin and Trimble, they can still be useful when doing field transect surveys where each individual needs to track their own location and data. These apps, such as MotionX and others, are free or nearly free, and they are intuitive and simple to use for students and others who are not familiar with the operation of dedicated GPS units.

We used the free MotionX iPhone app (https://gps.motionx.com) for field work in 2018, with a group of 4 students and a faculty supervisor doing forestry parcel surveys (Figure 14.8 and 14.9). Each student used their own iPhone and after one, quick orientation session on campus before departure, they were able to track their field transects, geotag ground photos, and collect field attribute data in the field without difficulty. None had ever used similar tools before.

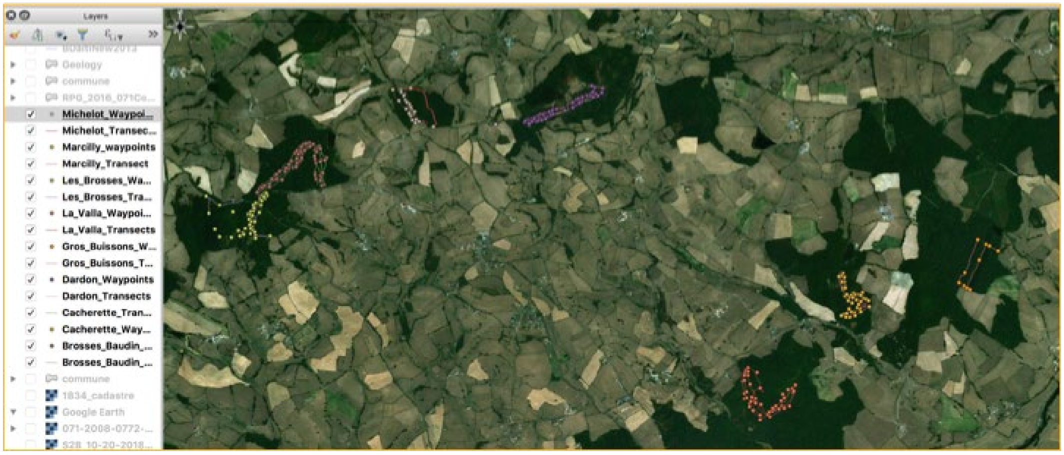


Figure 14.8. Field survey transects in the forested areas of our study area, displayed in QGIS. These were collected in 2018, by a team of four students and one faculty advisor, all using their own smart phones and the free MotionX GPS app. The field transects are shown in the forested (dark green) areas. QGIS screen image courtesy Scott Madry.

Figure 14.9 shows field transects through the various forests after the data were downloaded to our project QGIS database. The GPS transects are overlaid on a high resolution satellite image in our database. These data were collected by the field team each night after a day's work, and were transmitted via the internet to our project GIS in the U.S., where they were reviewed and entered into our QGIS database after quality control checks each evening. The field crews then had access to the previous day's field work the next morning when they were ready to start work again.

Our project has continually evolved over the years in our field survey approaches and the use of the available technologies, and this process continues.

Figure 14.9. Showing a detailed enlargement of one forest and the transects that were walked by our students. Ground photos and field attribute data were collected and integrated into our project QGIS database each evening. QGIS screen image courtesy Scott Madry.

Case study from the Virunga Volcano region of Uganda, Rwanda, and the Democratic Republic or the Congo

In the late 1990s and early 2000s the author participated in a major research project of Mountain gorilla (*Gorilla beringei beringei*) conservation in the Virunga volcano region of Rwanda, Uganda, and the Democratic Republic of the Congo (Madry 2007, 2008, 2015). This was a major primate ecology project, seeking to understand the relationships of the several mountain gorilla groups in the area, how they interacted with each other and how they moved about the landscape and utilized different vegetation zones as these changed throughout the year (Figure 14.19). We also conducted an extensive anti-poaching program due to the high amount of illegal poaching in the reserve. A GIS database was created, including historical maps, including a 1:100,000 topographic map at the Belgian Royal Museum for Central Africa that was created by the Belgian Colonial Service in 1938, which was the best topo map currently available for the entire region (!). We also acquired recent RADAR satellite imagery acquired by NASA for the project, as well as field vegetation and land use data (Figure 14.11).

GPS systems were used by the anti-poaching rangers in the field to map both the daily movement and activities of the various gorilla groups over time, as well as to map locations of snares, traps, and evidence of poachers such as camps. These data were integrated into the project GIS for both basic scientific research regarding the ecology of the gorillas within the Virunga reserve, and also for use by the anti-poaching patrols to focus their efforts to better protect the gorillas (Steklis et al. 2005 and 2007). This work, carried on by others, continues to this day and has significantly improved the long-term survival potential of these magnificent and highly endangered creatures. This is an excellent example of the potential that integrated technologies can have for complex environmental and ecological research programs, even in very remote and inaccessible locations.

Figure 14.10 Researcher Netzin Steklis, a very early model GPS unit, and a friend in the Virunga reserve. Photo by Dieter Steklis.

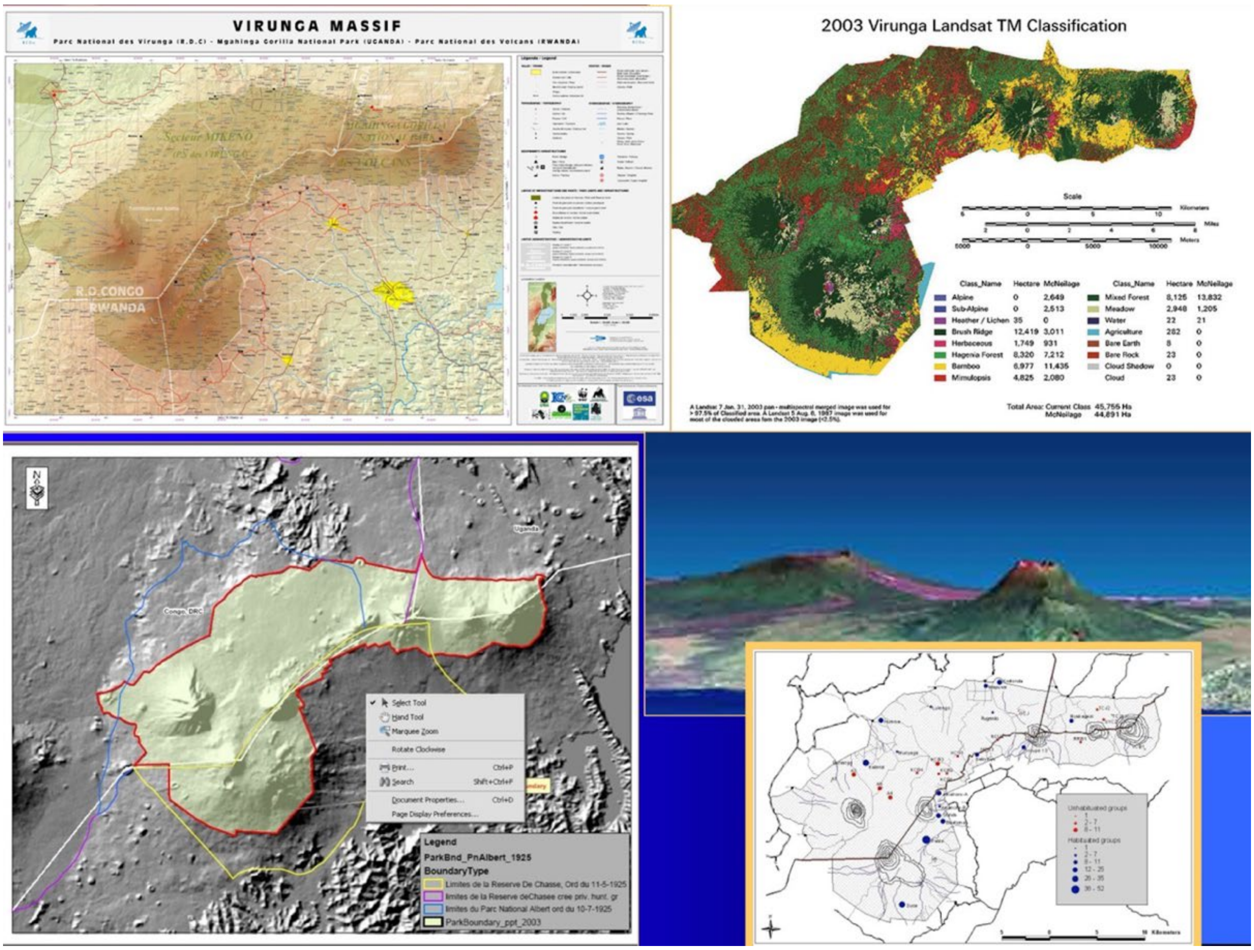


Figure 14.11. Four maps of the Virunga Gorilla reserve in Africa. Clockwise from top left, a recent topographic map derived from satellite imagery, a vegetation map produced from GPS fieldwork and satellite imagery, A 3-D view of the region using GIS and overlaid satellite imagery, a black and white map showing the GPS-derived location and movement of different gorilla groups, and a Digital Elevation Map of the region derived from satellite imagery. Images courtesy Scott Madry and the Dian Fossey Gorilla Fund.

Proper Field Data Collection Methods

It is important to establish a coherent and structured field collection strategy before you begin, and to use this in all field work conducted in a given field season. Always test your equipment and methods at home before you deploy to the field, and work out any problems or issues before you are consuming valuable (and costly) field days, or have to redo work. The use of checklists and standardized procedures ensure that everyone is collecting their data using the same methods. It is always a good idea to also collect and maintain analog field notes in case there are technical issues with the field computers, which can happen. We have conducted sample field tests using our GPS and digital map overlays at home before traveling to the field to ensure that the entire process, from first field transects through entering the final data into the GIS, actually works as planned, and to catch any issues before the field season begins. Careful quality control and review of the data collected, preferably each night after the data are collected, is important. Attention to safety issues, especially if students are involved in the fieldwork, is an important component of your planning, and there should be a consideration of the potential risks involved, and how you will respond in the event of a medical problem or other emergency in the field.

The digital field GPS data collected are of very limited size and complexity, and are generally archived within the project GIS system as vector point, line, and polygon data with their associated attributes or as geotagged raster photos. It is vital to acquire and maintain good field notes as well, and these should also be archived appropriately for long term conservation (Chapter 15). There are no copyright issues with using data from the currently available GNSS systems, unlike some commercial satellite imagery or copyrighted maps, and you are free to share, copy, and use these GNSS data without restrictions. Proper metadata and paradata should be collected and archived so that the specific parameters of the data collection methods are saved for future users, including the type of receiver and positional precision, so that future analysts can properly understand the parameters and quality of the data that were acquired, in order to understand their limitations and appropriate use.

What does this have to do with Historical Ecology?

Clearly, the use of GNSS-enabled field data loggers provided us with important capabilities that can be useful in many aspects of Historical Ecology research and beyond. PNT-enabled field receivers link together our field work with precise location and time data, allowing our field reconnaissance and data collection to be quickly integrated into the context of the project GIS system. This allows our field recordings to be spatially connected with other spatial data such as historical maps and aerial and satellite remote sensing imagery, geotagged photos, pond pollwn cores, ecological samples, etc. Multiple field researchers collecting environmental data can quickly use a field data logger to collect standardized environmental, position, and time data using digital field forms and all of these can be quickly uploaded and made accessible to the entire team through the project GIS. These systems can assist in the accurate georegistration of satellite or airborne imagery, and in the field verification of digital image products such as thematic vegetation classifications of remote sensing data. We can accurately collect 1 to 1 field data directly into our GIS, mapping old roadways, vegetation zones, hedges, or other features. Such receivers are also very useful in mapping aerial surveys, and prospecting tracks and accurately identifying the locations of features discovered from the air, something that was very difficult before the advent of hand-held GPS receivers. Geotagging of field photos and the routine collection of field images by all project participants is of real value. These receivers can also be used in the other direction as well, in that we can download random or stratified field locations for sampling strategies, or the results of computer models such as predictive models or vegetation classifications, and we can then download these positions to our PNT receiver and easily navigate to these precise locations on the landscape to investigate. So these receivers can be used in both directions, if you will. PNT field receivers provide us with an easy-to-use and inexpensive way to link our field data collections with accurate positioning and integration into our project GIS for analysis and presentation, so put them to use in your project.

Conclusions

Satellite Positioning, Navigation, and Timing (PNT) systems are now an invisible but vital aspect of our lives. They enable and drive many daily capabilities that we take for granted, and it will only become more enmeshed with our ever more technological and digital world over time. PNT and related field data collection tools and methods, providing the recording of precise locations and time, can be a vital aspect of Historical Ecology research, if we harness this powerful capability appropriately. Accurate field measurements are a vital component of our work and these existing and emerging data recording technologies enable our work in important ways. While many PNT-enabled field data systems exist, their use is generally simple and straightforward. Proper training and attention to detail are still vital, and always test out your methods and processes before going into the field to ensure that everything is working correctly. Make certain that all persons collecting data are using the same approach and are collecting data in the same way for comparability. Conduct quality controls, and back up your data and ensure that analog copies are available and that you create and archive both the data and metadata for future use.

Emerging technologies (Chapter 16), have very strong intersections with these field data collection technologies and methods. New and evolving methods for automatic in situ data collection networks, drone photography, AI, and automatic statistical analysis of field data, and more are emerging which have the potential for revolutionizing these aspects of our work. These all involve PNT, so the future of Historical Ecology will be very interesting. The key point is to realize that these capabilities exist, are quite affordable, are simple to use, and can be incorporated directly into our work both now and in the future.

References

Madry, Scott. 2015. Global Navigation Satellite Systems and Their Applications Springer Press

Madry, Scott. 2008. "Des gorilles du Rwanda aux sites archéologiques de la vallée de l'Arroux, Introduction aux nouveaux outiles de cartographie et d'analyse spatiale". in: "La Cartographie au Service de la Recherche et de l'Aménagement du Territoire", Centre Archéologique Européen, Glux-en-Glenne, France.

Madry, Scott. 2007. "*Hic sunt dracones* (Here be dragons): The Integration of Historical Cartographic Data into Geographic Information Systems." In: *Between Dirt and Discussion: Methods, Materials, and Interpretation in Historical Archaeology*. Steven N. Archer and Kevin M. Bartoy, eds. Springer, New York, pp 33-60.

Madry, S. et al. 2015. Water and Landscape Dynamics in Southern Burgundy: Three and a Half Centuries of Water Management in an Agricultural Landscape by S. Madry, E. Jones, A. Tickner and D. S. Murray. *Journal of Water History 7*(3):301-335.

Steklis, Dieter, Netzin Steklis, Scott Madry, and Nick Foust. 2005. An Integrated Geomatics Research Program in Mountain Gorilla Conservation in the Virungas. In: *Conservation in the 21st Century: Gorillas as a Case Study*, T. Stoinski, H. D. Steklis, and P.T. Mehlman, eds., Kluwer Academic Press.

Steklis, Dieter, Netzin Steklis, Scott Madry, and Nick Foust. 2007. "GIS Applications for Gorilla Behavior and Habitat Analyses" in: *GIS Best Practices: GIS for Wildlife Conservation*, ESRI Press 2007 pp. 15-22 available online at: http://www.esri.com/library/bestpractices/wildlife-conservation.pdf

Teunissen, Peter J.G., Montenbruck, Oliver (Eds.) 2017. Springer Handbook of Global Navigation Satellite Systems. Springer International Publishing.

CHAPTER 15

DIGITAL ARCHIVING AND DATA CONSERVATION, SHARING, AND ACCESS

GREGORY N. JANSEN

Digital archiving is a vital new supporting technology for Historical Ecology, and is, at this time, rarely used.[1] This chapter will present the basics of this exciting new field and how it can be relevant to the digitization, storing, access, and archiving of data in support of Human Ecology projects and the sharing of information on large projects. We will describe the practice of digital archiving as it applies to data-driven projects like Historical Ecology and cover all the essential archival concepts to bear in mind while adapting archival practices for your project, including provenance, original order, fixity, durable storage, disaster recovery, and more. As with any research endeavor, there are a variety of scales and maturity levels within Historical Ecology projects, especially with regard to digital workflows and storage. These core archival concepts can be applied to any scale of Historical Ecology project, from a single researcher with a single computer to a team of a dozen or more international researchers working within a data center or with cloud storage.

Professional Help

Before we jump into archival theory, perhaps the most strategic first step your project can make is to avoid mistakes and duplication by identifying any institutional or archival resources that are already available to you. If your project includes connections to an academic or cultural heritage institution, or if you can establish such a connection, you will do well to inquire with the archivists at those institutions as early as possible. A professional digital archivist will be able to tell you if their institution includes materials like your project in their collecting policies. If so, then you may obtain consulting on your data practices and the use of institutional services, such as a trustworthy digital repository for long term data storage. Archivists can recommend appropriate strategies based on your particular data and workflow. Lastly, the research institution can preserve your data and provide access to it for far longer than a team of independent researchers can possibly manage themselves. So, before you read much further, consider the resources you have available and take full advantage of any professional services at an affiliated institution. Having said that, even with professionals involved, the archival theory and practice we outline here can inform your research practices and can be a refreshing lens for thinking about data-driven projects.

Content, Context, and Structure

When an archivist approaches a record, whether digital or in physical form, they are concerned with the three fundamental aspects of content, context, and structure. Archives as a discipline is the practice of preserving and providing access to records with these three aspects as intact as possible. Content is the intellectual substance of the material or work, such as its text, data points, images, or sounds. Context is the organizational and social circumstances of the object, i.e. who created it, in what organization, and to what purpose. Finally, the structure is how a collection of objects, works, or items were organized, interrelated, and presented. These three aspects taken together are considered to be the archival record. An important observation at this point is that the records that make up a collection are not like the books in a library, which are shelved together for storage and discovery purposes. Unlike books, records that make up archival collections stick together in a structure that lends additional meaning to them. Another departure from library-style collections is that archival materials are often described in aggregations and at a higher-level than individual items. So a letter may be stored within a series of correspondence between two people. The series will then be described with context about the relationship between the letter writers. This treatment of individual items as an aggregate is a helpful concept for digital archiving of your research data, where many digital products may share the same origin and workflow and be likewise described at a high level.

Perhaps the most salient concept in archives is provenance, the preservation of the original context of an item, including its origin, chain of custody, and ownership. In museum collections it is this fully detailed provenance that establishes that a painting was created by Vermeer rather than a skillful copycat. Provenance is a key property that establishes trustworthiness, such that a visitor can believe that an item is authentic and that any alterations are known. In the digital world the ease of copying and sending data to new places often wreaks havoc on digital provenance. For, once a document is emailed around the world a few times, nobody can easily say who created it or where the latest copy is stored. It becomes difficult to trust that the copy you have is indeed the latest and best copy. The convenience and fungibility of digital data makes provenance a particular challenge. Capturing provenance during a digital project requires additional consideration and effort. Archivists maintain provenance by cleanly separating collections into divisions, based on their different origins, and preserving notes on the original context in descriptive records. They maintain checksums for each file and an irrefutable log of how they are transmitted and preserved. In the realm of ecological data, provenance may be identified in a fine grained way, such as recording the identity, method, and configuration of the instrument that was used to make observations within a dataset. In some settings, such as Earth remote sensing and radiocarbon dating, this level of detail is useful beyond the individual project and may be essential to the reproducibility and contestability of the research. Another key component in scientific provenance, especially in multidisciplinary fields such as Historical Ecology, is the capture of data processing workflows, such as data cleaning steps and those methods used to extract and generalize raw observations into the features of a particular mathematical model, as discussed in the chapters on GIS and remote sensing. When data from many scientific disciplines is combined in one project it is easy for researchers to make assumptions about how data has been handled outside of their specific field. Provenance is a helpful concept for identifying the key steps in the lifecycle of your data and deciding which details may matter to later consumers of that data and related products in the broader context of historical ecology.

Alongside and in support of provenance, there is the idea of order. In archival practice we talk about original order as the organizational structure of the records that was established by the creators of the records. Archivists intend to preserve, as far as practical, the original structure in which records were created or used by a particular person or organization. Sometimes these original structures are peculiar, sloppy, or haphazard and not especially helpful to the later visitors to these collections. However, the original order is supplemented by indices and catalogs that are created by archivists to help visitors find their way into the materials. Whereas in physical or document collections the original order consists in folders, boxes, and shelves, in digital collections the original order is usually a mix of drives (or filesystems), nested folder structures, and package files (archival files, such as ZIP files). Sometimes the original structures that house modern digital materials include specialized data systems, such as geographic information systems (GIS), social media accounts, and cloud-based services. Digital data may be managed and used in a variety of "data silos" that are each accessed in their own way and that may be hard to preserve or replicate outside of that digital home. For example, it is a harder problem to preserve the original order of a Facebook account outside of Facebook, than it is to preserve the original order of a hard drive outside of the original device. It may be possible to export the complete data from its digital origin online, but replicating how such data was displayed is a challenge. A common practice is to export data in a way that preserves the logical structure in as much detail as possible; Then take screenshots or short videos to capture the way that a complex structure of objects is rendered for display to users. With respect to digital data we have a unique ability to produce multiple renderings or visualizations which may highlight important areas or details that are easy to miss.

Having established all of the structure and context that surround each archival object, we now finally come to the object itself, the content. From biological specimens to works of art; from video games to office documents, archival content comes in many forms and formats, each with intrinsic challenges for storage, preservation, and access. The content objects in digital collections, even when exported from a digital service, boil down to data stored in files.

Filesystems, Files, and Formats

Files can only be stored inside of a file system, such as NTFS, which is common on MS Windows computers, HFS (MacOS), or EXT3 (Linux). Within a physical storage device, such as a USB drive, the file system tracks files by their name and folder path and may also store a few other properties for each file, such as the owner, file size, the modification data, and sometimes the creation date. Some file systems also support custom, user-assigned file properties. Aside from these names and properties, the file system treats each file the same way, as a container for reading and writing a stream of binary data, or bytes.

The internal structure of a file is determined by the software and the user that created it. Some files are created automatically without user involvement, say by the operating system, while others are created with minimal intervention from application software, such as when a user writes a plain text file. Most files that we care about are created by people using application software, such as MS Word or Adobe Photoshop. In these situations the internal structure of the file follows strict rules laid down by the software designer that we call the file format. Sometimes the rules are public knowledge and well-documented, but other times those rules are a trade secret and undocumented. When the intellectual content of a file is embedded in a secret or proprietary file format, it becomes difficult to access outside of a running copy of the application software.

The intrinsic properties of a file are mostly determined by the rules of the format and the design of the software. For instance, MS Word stores data about the user who created each file and a record of the changes made by each subsequent user. Some camera or fitness software will record the geographic location of the device inside of a photo file or a workout log, while other software that uses the same file format may not record that detail. The file's format determines the set of required and optional information within a file, but users may always establish additional conventions to encode more data, such as a rule that says that a document file always includes a version number and publication date. Similarly, file formats are often based on other file formats, adopting all of the rules from the preceding format, but adding some new ones. Newer versions of Microsoft Word would often add new rules in order to support new software features. For example, many formats are based on the ZIP file format, which allows software designers to bundle many separate files, each with their own format, within one file that represents the intellectual entire work. Modern MS Office formats are based on the standard ZIP format. Modern software often creates files with several levels of composition, placing each element of an intellectual work, such as text, images, and sounds, in the most suitable format, then packaging and compressing these along with structural information that fits them together in one viewable or playable file.

Technical Debt and Large Digital Projects

As a digital enterprise develops, there is demand to create greater and greater interactivity with collected data and media, these include new visualizations that demonstrate findings or interfaces that engage with users. That new interactivity is created through software and that software must be developed, configured, and maintained by people with the appropriate expertise. Someone, either in-house or a third-party, must maintain all of the software or it quickly becomes out of date and stops playing its part in the software ecosystem. As a software project grows more complex, there is a sort of technical debt that accumulates and demands "interest payments". Digital enterprises use the concept of technical debt to refer to the software investments they must sustain in order to keep the entire project technically viable. It includes the activity of maintaining code, but also the maintenance of the staff expertise required to deploy and configure the entire software system. As a rule technical debt is ignored by nascent digital enterprises until they are surrounded by it and realize that half of staff time is spent keeping systems running instead of developing new features and services.

Historical Ecology projects vary widely in the level of software employed. Some consist of collections of shared files while others include large geographical databases, sophisticated websites, and custom data processing software. The more sophisticated projects are generally more difficult to keep running and likewise more difficult to capture faithfully and archive for posterity. As we dive into more specific strategies for archiving a Historical Ecology project you may find that technical debt is a useful lens for reflecting on technology choices.

High Fidelity Preservation versus Core Properties

Many normal websites can be captured page-by-page as browseable archives by dedicated web archiving tools, such as HTTrack[2]. However, the more high touch, dynamic, and interactive experience of Historical Ecology that exists, say, in a sophisticated online research portal, is perhaps most faithfully preserved by taking steps to make that infrastructure itself more durable and sustainable. For instance, adding reliable backup and recovery procedures and careful documenting the systems involved. It is difficult to faithfully capture the browser experience of such dynamic sites with current web archiving tools. Typically the best alternative is to capture the website as it is experienced by making a movie or a slideshow that preserves a snapshot of the interactivity for a potential future audience or researcher. We then try to identify and also preserve the core collection data and media that are used to construct the experience of the website. The digital archive system is an excellent place to store these items, along with documentation and perhaps core data processing code that might be useful to future researchers or helpful to someone trying to recreate a similar user experience.

Getting Started: Rapid Assessment

Digital Asset Inventory

The first step in creating an archiving plan for your project is to build an inventory or summary of the data you have accumulated and any incoming streams of new data. The inventory will inform your next steps, such as formulating an appropriate capture and preservation plan. Hopefully, in a multidisciplinary project, the inventory can be supplemented by short interviews with the data producers, but often it is the case that a producer is not available for some reason. You want to start by grouping your data into large "buckets" with similar provenance. It may be useful to examine the various layers in your GIS to disentangle the various buckets of data. A simple spreadsheet is a good way to organize this information. There can be a fair amount of detective work involved in gathering even at this high level data, so keep it simple for now. Here is a short list of the data to gather on each bucket:

- Subject - What is the data about?
- Rationale - Why is the data part of your project? What is its function?
- Origin - Where did it come from?
- Producer - Who created the data?
- Medium - Where specifically is the data stored? For example, what network drive or what optical disc, etc..
- Format - What file formats are involved?
- Access - How is the data accessed and used?
- Owner - Who owns the intellectual property?
- Rights - By what license or whose permission is the data used?
- Privacy - Does the data contain any personally identifiable information or sensitive geographical or cultural information, such as confidential ethnographic informant data?
- Activity - Is this data still being produced and growing or is it no longer active?

You may end up with a list of five or six sets of digital materials if your project is relatively new and small. Larger projects may list out twelve or thirteen different types of data, that must be further divided into different sets by their provenance, for example all of the digital aerial photographs may not originate with the same photographer, instrument, or organization. They may not all have the same access or publication rights. These different sets of aerial photographs will need to be listed as separate inventory buckets. Ideally you can organize all your materials in this way and know with some detail what you will have in your custody. However, inevitably you will encounter a mess that exists somewhere in your project, materials of various origins thrown together without a clear organizing scheme. Don't freak out. This is an entirely normal state of affairs when professional archivists receive new deposits. The answer to a chaotic mess is that you can lump these materials together and do the best you can to describe them as an item in your inventory, including where you presently found them and as many supporting details as possible. A description might be something like, "Maps and Documents, duplicated in Burgundy 1992-1998" or "35mm Slides - 1981". You don't need to dive into every mess to tease out each and every single dataset. That could take a lifetime and it isn't helpful at this rapid assessment stage. So when you don't know the details, put such mixed materials in a "bucket" and keep moving.

Capacity Assessment

The other form of assessment is a reflection on the resources and time available to your archiving effort. Archiving is an ongoing act of stewardship, but you first have to obtain basic control and secure your materials. Further processing can take place with the knowledge that your materials are in durable storage. The initial phase to secure materials will require a lead person as well as a commitment to assist from colleagues and data producers. The initial phase will locate and secure the most vital materials against various risks of loss. If time and resources are severely limited, then your effort may need to retain a sharp focus on the critical task of locating and securing the data. In doing this you enable others to carry on later when more capacity is available.

The National Digital Stewardship Alliance (NDSA) has a simple model consisting in four levels of digital preservation (Table 15.1):

1. Protect the data
2. Know the data
3. Monitor the data
4. Repair the data

These levels are progressive, starting with the first and most important. Within each level the NDSA lists essential tasks within five categories of storage, integrity, control, metadata, and content. Their Levels of Preservation 2.0 planning grid is an excellent reference for evaluating your capacity and planning the steps in building your project's digital archives. If you only have the capacity to protect the data (level one), then that is what you should plan to accomplish at this phase.

Table 15.1. Levels of Preservation v2.0[3]

	Level 1: Protect the Data	Level 2: Know the Data
Storage	Have two complete copies in separate locations. Document all storage media where content is stored. Put content into stable storage.	Have three complete copies with at least one copy in a separate geographic location. Document storage and storage media indicating the resources and dependencies they require to function.
Integrity	Verify integrity information if it has been provided with the content. Generate integrity information if not provided with the content. Virus check all content; isolate content for quarantine as needed.	Verify integrity information when moving or copying content. Use write-blockers when working with original media. Backup integrity information and store copy in a separate location from the content.
Control	Determine the human and software agents that should be authorized to read, write, move, and delete content.	Document the human and software agents authorized to read, write, move, and delete content and apply these.
Metadata	Create inventory of content, also documenting current storage locations. Backup inventory and store at least one copy separately from content.	Store enough metadata to know what the content is (this might include some combination of administrative, technical, descriptive, preservation, and structural)
Content	Document file formats and other essential content characteristics including how and when these were identified.	Verify file formats and other essential content characteristics. Build relationships with content creators to encourage sustainable file choices.

We reproduce the first two levels of preservation above and encourage you to visit the website[4] for further details and other helpful guides.

Preservation Planning

As you plan long term preservation activities, you want to decide what preservation levels are practical for each bucket in your inventory. As Historical Ecology often borrows datasets, photographs, and other materials, you might decide to focus your preservation efforts on the materials that are most original and unique to your project. Find out which materials in your inventory are being preserved elsewhere, such as by the research institution that supported the original study? If data is being reliably preserved at a research institution with a suitable retention schedule, then you might consider offloading the digital preservation work and citing that data with a persistent identifier and link. If you are less sure of preservation at the original host institution, you may still want to monitor that preservation activities are ongoing at the host institution and count their copy as one of several copies of the data.

Using the U.S. NDSA guidelines, create a plan that lists out which preservation level you choose as a reasonable goal for each bucket in your inventory. The plan might include more advanced preservation levels for truly unique and irreplaceable materials and light treatment for materials that are found elsewhere or have physical analogs. In any case, the first step will be to ensure all of your digital materials are protected at level one. If you end up reaching your initial goals for preserving materials, then you can revisit the plan and decide if a higher level goal is worth pursuing.

The second part of your plan will detail how you intend to fulfill the chosen level of preservation for each of the five NDSA categories. This includes the specific tools, services, and techniques you will use. In the following section on archival technique we will explore the categories of storage, integrity, control, metadata, and content to review basic requirements and make a few recommendations that will help you get started.

Digital Preservation Techniques

Storage

We all know that making a backup copy of materials is a hedge against all kinds of damages to the original copy, such as a hard drive crash or a stolen laptop. A key principle in digital archives is that additional copies will keep the material safer still. Each copy safeguards against the loss of all of the other copies. The caveat is that each copy introduces some overhead and costs. Someone must know how to recover the data from all of the different copies using rehearsed procedures and this person also needs a backup. We use the term replica for each copy of a digital object and the process of distributing or updating the copies is called replication. A strategy that mitigates risk by making copies is called a replication strategy. Replication strategies may be designed to address both specific and general threats to digital materials. First of all, data storage of any kind is at risk due to mechanical failure, disaster, and human error. On top of these ever present risks, some copies may face specific risks, such as discontinued funding, closure of a host institution, policy changes, or a sudden discontinuation of third-party cloud services. A replication strategy can mitigate risks by placing one or more copies out of reach of any specific threat. For example, to mitigate the risk of data loss due to a localized disaster we ensure that we have a replica in two or more different geographic areas. To mitigate the risk that an institution closes down, taking their data storage offline, we place copies at other institutions or with third-party storage services.

To protect your data, the first step is to create one additional copy in a separate location as soon as possible. The second copy will instantly and dramatically lower your risk of data loss, as long as the storage device is independent of the first copy and not in exactly the same server room. Since time is of the essence, you should move with deliberate haste, in months not years, picking a location that is readily available to your project. This can be cloud storage, your institution's storage service, or a separate researcher's computer hard drive, as long as the storage location is persistent, not temporary. Your decision depends upon the resources available to your project. After a second copy has been made you can better afford the time it takes to investigate further storage options and consider the specific risks to your project data.

When replicating data for the purpose of backup, there are a few concerns you must keep in mind, some of which we will explore in the next section on integrity. One that comes up when looking for storage services is that backup/recovery storage services can be quite distinct from normal storage, especially when dealing with terabytes of data. One way to save money on backup storage is to use a "high-latency" storage service. This means that data is stored on magnetic tape or some kind of optical disc and that it must be reloaded from the medium before the data recovery can start. In other words, your data is not instantly available nor is it accessible in a piecemeal fashion (random access). Some very popular backup/recovery providers are high-latency and a good bargain, such as Amazon Glacier (or Deep Glacier for even higher latency) or tape services such as Iron Mountain. When high-latency data is at rest, you pay very little to persist it. Instead the costs rise when you need to access the data for recovery purposes. In fact you are paying for use of low-latency (fast, random access) storage and network bandwidth or transportation during the data recovery process.

When shopping for storage there are three common-sense factors to keep in mind. Durability is the statistical risk of data loss and should be a published, no-nonsense metric from the storage provider. As an example the Amazon Glacier services design their system for a durability of 99.999999999% (11 nines). Availability is the protocols and latencies involved in accessing the data. These must be adequate to complete both backup and recovery in a reasonable time frame for your project. In order to know your requirements for availability, you must know your acceptable time to recover and your specific recovery procedure. If a copy takes several weeks to recover internationally on optical discs, that may be fine. Your project must be able to do without a primary copy for those weeks. The last factor is cost naturally. You have to be able to afford the cost to persist the copy over time and, in case of disaster, the cost of restoring the data. Be aware that many IT vendors engage in aggressive marketing and unclear pricing. Web searches on "backup services" or even some of these technical topics will turn up a trove of marketing material masquerading as how-to guides, technical articles, workshops, and even IT conferences. Look for a clear menu of services that lists out prices alongside metrics for service uptime and data durability. Try to find objective technical benchmarks and reviews of services by a trustworthy organization. I use a site called "Alternative To"[5] and search there for competitors to popular cloud backup providers such as Amazon Glacier, Google Coldline, and Backblaze.

Another important distinction to note before we leave storage is that synchronization services are not the same as backup storage. Synchronization services keep multiple copies of your files updated across two or more computers or devices. One popular example is the Apple iCloud for synchronizing music and media collections. The main problem with synchronization is that change is replicated too fast to offer any safeguards against operator error. If you were to delete the primary replica of a digital object, the sync service might instantly delete all of the other copies that it controls on other devices. Synchronization services are not a sound replication strategy for many reasons, but mostly because they replicate changes instantly and because they give one service too much span of control over your copies, meaning that any failure or misconfiguration in the synchronization service would be catastrophic. Along similar lines, a single backup service alone is not a sound replication strategy, even if used to store multiple copies, because of the dependency on a specific backup software and corporation, which can fail, be misconfigured, or become obsolete.

Integrity

We've discussed replication strategies and how to evaluate storage services. Now we turn to the replication process itself and how it is and isn't different from simply dragging and dropping a couple of folders onto a network drive. Integrity is the quality of digital objects being whole and unaltered through tampering, loss, or corruption. Integrity also includes the completeness of a given collection of objects; That nothing is missing. We want to ensure that the digital objects and collections have this quality of integrity and we also want to have documentation that allows us to verify integrity over time and prove it to others. You want to establish integrity information for your files as soon as is practical, even during the process of transferring materials in your high-level inventory on local storage.

The primary integrity information you need to capture for individual files is fixity in the form of a file digest. A digest, also known as a digital signature, is a long number that is created when you feed the entire byte stream of a file into one of several digest algorithms. These algorithms consume and "digest" the file content. If the file is altered in any way, the digest number will change too. By comparing an older digest number with a newly computed one, we can verify that the byte stream is intact. This allows us to verify a replica's fixity without having to re-read the byte stream of the primary copy, for example. A common digest algorithm for decades is MD5, while a more modern one is SHA256. Digests are also used in digital authentication and encryption, where they must block malicious agents from spoofing a byte stream, so they are more than adequate for the detection of more accidental or naturally occurring file corruption.

There is a very helpful standard that I recommend you use to build and organize your integrity information, BagIt v1.0[6], which was adopted as an Internet-Draft by the Internet Engineering Task Force (IETF) in 2018 (Figure 15.1). There is also a free tool from the US Library of Congress, python bagit[7], which meets this standard and helps you build "bags" of files along with their integrity information in the form of manifest files that contain calculated digests. A bag in the BagIt sense is a folder of files that follow a certain naming convention and may include manifests and other control files.

```
<base directory>/
|
+-- bagit.txt
|
+-- manifest-<algorithm>.txt
|
+-- [additional tag files]
|
+-- data/
|     |
|     +-- [payload files]
|
+-- [tag directories]/
      |
      +-- [tag files]
```

Figure 15.1. IETF BagIt v1.0 Folder Structure.

When you run the bagit command-line tool on a folder of your choosing, it moves the folder contents into a data subfolder and proceeds to build a manifest with digests for each included file. Another command allows you to verify any existing digests in the bag manifests. If you compress the folder into a ZIP or similar file, then send it around the world, you can simply decompress the folder again and verify the integrity of the contents.
Note: When bagit moves payload files into the data subfolder it does so as a logical move as opposed to a physical move. The files involved stay in the same location on the physical storage medium, but the filesystem catalog is updated to reflect their new logical location or path. Files that are reorganized within the same filesystem generally remain "at rest."

The same exact workflow applies in the transfer of files into the future on a storage device. A convention like this one allows you to deal with files in batches that travel together, which can cut costs significantly in transfers to cloud-based archival storage. Finally, a BagIt bag allows you to treat many different storage technologies as "black boxes", which can be used interchangeably in your archival workflow.
As you gather together digital files and consolidate them into the buckets of your high-level inventory, one way to reliably transfer groups of files from colleagues is to have them create and send a compressed bag file. This establishes fixity as early as possible and, through bag verification upon receipt, guards against file corruption during any number of file transfers.

Control

In this context control refers to administrative control over digital objects. It is important to consider who will need to have the ability to read, write, update, and delete your files. Often the best way to approach this is to define some roles within the archiving team and the larger project. In Historical Ecology we can probably assume that there is a group of colleagues, all of whom should have the ability to read the archive at some point. A smaller group would have the ability to create and update files in the archive and an even smaller group should be able to delete items. At first, in achieving your level one goals, you don't need to enforce these access rules on data platforms. A small group will need to configure your storage, handle the creation of bags, and replicate them to other storage systems. This same group can facilitate access, when needed, for the rest of the project members. The common name for this workflow is a "dark archive", one which has no publicly accessible interface and all access is mediated by a technical team. Deciding on proper controls at this stage is not a theoretical exercise, as the technical team will need consistent guidelines on who is authorized to request copies or send updated versions of files.

One way to document your controls within a Historical Ecology project is to designate certain people as the stewards of certain data. These are the people who would be expected to produce or bring in an updated version of the files. They get the create and update permissions within that part of your inventory. The technical team would have to check with them if someone else were to request such a change. This may roughly translate to the "owner" column in your inventory, but in many projects the owner will be an institution or a single person. There may be more than one steward for a part of your inventory. Much depends upon the scale of your data and the number of people involved. If your project is still small, the steward and the tech team that configures the storage may indeed be one and the same person.

Metadata

Metadata is simply information about data objects, singly or in groups. In digital archives we break metadata down into categories of descriptive, administrative, technical, and provenance. Descriptive metadata describes the content in terms that resemble a library catalog, such attributes as the title, creator, subject, type or genre, and length. At the early stages of building an archive this metadata should be created at the highest level that still makes sense. The best case would be to have the subject matter expert be the creator of the records, but this is not always possible. Your inventory buckets may be sufficient, or you may want to create a level of description below certain buckets with distinct subfolders. In institutional archives and records management there is deep expertise in collection arrangement and description, including hierarchical organization of material description into collections, sub-groups, series, sub-series, and folders. Like ourselves, they will certainly begin with a light description of top-level level divisions, and then secure the data, before exploring deeper levels of description. Traditional paper archives rarely include document level descriptions of materials as there simply isn't time available for this, aside from the papers of famous authors and other luminaries. Researchers in these archives will use higher-level descriptions to request a set of physical folders and then flip through the contents to find documents of interest. Since digital technology facilitates many forms of automation, including full text indexing and search, digital archives can provide greater assistance to researchers looking for specific information in a large collection.

Administrative metadata that we need at this stage is already listed out in the rapid inventory spreadsheet, namely ownership, intellectual property rights, licenses, and metadata about administrative controls. You will have already captured those at a high level.

Provenance metadata is the event record of custodial or preservation actions that have been taken on a digital object over time. An event is usually recorded for actions like virus scans, format migrations, or digest verifications, physical and/or legal transfer of custody. This record of events helps to prove that a digital object has been faithfully preserved over time. Events logs may be maintained within a digital asset management system, or a dedicated digital preservation repository. Short of such systems we can also maintain an event log in a spreadsheet or in a comma-separated text file. As with descriptions, we can record events in aggregate at this stage. For instance, when you verify that a BagIt transfer has been successful and all the files within are intact, then you can record an event in your event log stating who performed the verification, what software was used, the date, and path or filename of the bag that was verified.

You may have noticed that we failed to address technical metadata so far and it is because that metadata falls in the NDSA content category.

Content

Here we are concerned with the digital objects themselves. The advice from the NDSA at the first level is to document file formats and essential object characteristics. Technical metadata is this kind of information about the structure of an object. In physical archives this could be the binding style of a book, or the type of paper used for a photographic print. For our purposes in digital preservation we care about the file format and any structures that create dependencies between the files. You can say that essential characteristics are any details necessary to reproduce the intellectual content of an object. For instance, a GIS database is composed of several different files with different formats. All of them are necessary to reproduce the GIS database. A web page is similar, wherein one HTML file depends upon supporting image files and perhaps javascript and CSS files. There are helpful tools to help gather and record file format information, but these tools only rarely recognize compound objects, such as an ArcGIS shape folder.

Let's explore tools used to characterize files and produce technical metadata. A powerful tool used to characterize an entire folder full of files is Brunnhilde[8] (Figure 15.2). If you point the Brunnhilde tool at the data directory of a BagIt folder, or any folder, it will scan the contents and produce a detailed format report on file formats it discovers. It produces both a comma-separated text file report (CSV) and a more user-friendly

HTML report. Brunnhilde can even perform virus-scanning for you at this stage, using the free virus scanner, ClamAV[9]. Brunnhilde depends upon a prior project, Siegfried, for file format identification routines. If you want to know more about this topic, such as identification algorithms and the format signatures they use, you can find more on the Siegfried website[10]. Similar tools that you might also want to use include the FIDO tool from the Open Preservation Foundation[11] and the Unix/Linux file command. Note that digital collections often contain files that are unrecognized by all of the above format identification tools. When these tools fail to identify a file, it is best to look at the provenance and inquire as to how that file was produced; what software was used, etc.

File formats

Format	ID	Count
AppleDouble Resource Fork	fmt/503	466
ESRI Shapefile Projection (Well-Known Text) Format	fmt/320	210
dBASE Database	x-fmt/9	177
ESRI Arc/View Shapefile Index	fmt/277	126
ESRI Arc/View ShapeFile	x-fmt/235	126
ESRI Code Page File	fmt/1253	104
Esri Shapefile Geospatial Metadata File	fmt/1729	96
Plain Text File	x-fmt/111	88
Portable Network Graphics	fmt/12	79
ESRI Spatial Index File	fmt/319	58

Figure 15.2 Brunnhilde produced file formats report for a set of ESRI Shapefiles.

When an intellectual work is composed of several files, that structure isn't captured by Brunnhilde or other file analysis tools. Instead you may need to identify these composite items yourself through a specialized workflow that may or may not include some simple scripts to detect the relevant file name conventions. For example, the pages in a book are usually scanned as individual image files in a number sequence from something like "MyBook_p001.tiff" to "MyBook_p442.tiff".

As we approach digital preservation in Historical Ecology projects, we confront the issue of compound objects head on in the form of GIS databases. These structures combine data files, such as map images and geographic datasets, with configuration information that defines how those data files are folded together into the combined map and database (Figure 15.3).

When we consider migrating these files to newer formats, such that they can be accessed in contemporary software, we need to remember that migration of individual file formats may break file dependencies and invalidate configuration information. This is a key consideration for long term preservation of Historical Ecology databases. Migration of the GIS configuration files and supporting files must take the entire structure into account to preserve the intellectual contents. In the example above we can see several files with the same name and different file extensions. When appropriate, all of these should be migrated to new formats together, preferably using a QGIS-specific migration tool or script.

```
TRONFLUV_id.dbf
TRONFLUV_id.prj
TRONFLUV_id.qpj
TRONFLUV_id.shp
TRONFLUV_id.shx
```

Figure 15.3. A set of files for one QGIS database.

Assessment and Level 1 Preservation in the Historical Ecology of Burgundy Project

While writing this chapter that applies archival practices to Historical Ecology collections, I have been working with Scott Madry and his colleagues to conduct a rapid assessment and reach level 1 digital preservation of the vast materials collected from their Burgundy region project. Dr. Madry has been conducting archaeological and landscape research in Burgundy for more than 45 years, alongside fellow researchers, students, and community members. The project spans multiple disciplines and institutions, as well as multiple generations and continents. One hub of the project is clearly with a few scholars, presently including Scott Madry and Seth Murray, at two universities in North Carolina. The broadly defined project has collected materials that describe human activity and interaction with the landscape over a span of 2000 years. As colleagues have moved in and out of this project, the collected physical and digital materials have been carefully kept in homes and offices around the world, but they have never been processed and preserved as an archival collection. Two separate house fires have claimed a portion of the materials along with personal collections. Labs and offices have also flooded, causing extensive damage to materials. Meanwhile the digital portion of the project has grown substantially since the 1970s and includes more and more the digitized forms of materials from the pre-digital era. Much like the physical materials, the digital copies remain in homes and offices and are subject to the same types of losses.

Rapid Inventory

After some initial meetings we decided to use the project as a test case for the methods I laid out in the chapter, in particular, the initial assessment and the steps to Level 1 preservation as per NDSA guidelines. As current stewards of the project, Madry and Murray were able to hire a graduate student from North Carolina State University to begin the initial inventory of their collections. They created a shared spreadsheet on Google Docs to identify the initial buckets of data that may later become archival series (Figure 15.4). After many passes through the inventory, they collected much of the information desired on the content, its provenance, ownership, format, and more.

An overview of the project collection is essential for discussing the next step to take in preserving the materials. Such an inventory is rarely fully complete before proceeding, but it must be good enough to understand the breadth and depth of the material involved. In digital collections this amounts to the scale of the data, file formats, geographic dispersal, ownership, and access sensitivity. Ownership is one data point that may be misleading at first for digital data. It is primarily used to establish a clear deed of gift, which transfers ownership to a collecting institution. In historical studies much of the source material may be in the public domain, but nonetheless photographs or other likenesses of that data may be owned by the photographer or producers. Intellectual works are similarly the property of their producers, generally, although articles, photographs, and data files may have different ownership if they are produced under contract. Sometimes ownership will require extensive research to establish according to any sort of legal standard. For the initial inventory a best guess is sufficient for planning purposes.

	A	B	C	D	E	F	G
1	Product	Rationale	Origin	Producer(s)	Contributor	Medium	Format
15	Maps	Maps of Burgundy	Multiple, IGN, BNF, AN, LOC	Multiple, IGN, BNF, AN, LOC		Paper	Analog
16	Maps digital	Scanned maps	Multiple, IGN, BN	Multiple, IGN, BNF, AN, LOC		Digital	Digital
17	Vertical aerials analog	1945 aerials	US DOD	US DOD			Analog
18	Vertical aerials digital	1945 aerials	US DOD				Digital
19	IGN aerials digital	IGN mapping ph	IGN				Digital
20	Oblique aerials	aerail photos	Multiple				Analog
21	Oblique aerials digital	aerail photos					Digital
22	Remote Sensing data	Satellite imagery of various dates	Landsat, ESA, JAXA	US, ESA, Japan			Digital
23	GPS files	GPS ground		[illegible]			[illegible]

Figure 15.4. Sample rows and columns from the Burgundy Project Inventory.

Some of the other columns not shown above for the Burgundy materials include whether the material is digital, the owner, repository location (if applicable), privacy level, whether active or not, size, location, and keywords. In a matter of weeks enough information had been gathered to proceed with the next steps in the plan, namely capacity assessment. The Burgundy Project has no permanent full-time staff of its own. Instead it relies upon the effort of a loose confederation of scholars. This effort is dictated by their other commitments and the availability of funding for travel, scientific equipment, and graduate assistants. Funding is mainly awarded for new research that produces new piles of data, and not for the preservation of legacy collections. Therefore the capacity of the Burgundy Project itself is fairly limited. They have access to existing personal computer equipment and the network storage drives that are supplied by their institutions for active work. They do not have a server room or storage infrastructure of their own, nor do they have access to a private cloud-based storage infrastructure. They have no ongoing source of funding to develop either of these storage infrastructures. So the capacity for preserving this information within the project itself is very limited.

However, being composed of a diverse group of scholars, the project has affiliations with multiple research institutions and these institutional partners may be able to help meet their needs. Through Scott Madry, we reached out to the university archivist at the University of North Carolina at Chapel Hill (UNC). In our meeting they shared all of the services that UNC is able to provide for faculty and which types of collection might fall under the university archives or special collections purview. While the Burgundy Project does not fall under the university archives collections policy, parts of it, such as papers and other academic works, may be submitted to the UNC institutional repository. This repository service is used to preserve access to academic works by faculty at UNC and mainly used for academic publications. The university archivist was also able to point us to the Odum Institute at UNC, which runs the DataVerse, the chief repository for scientific data that is produced on campus. At their urging we set up an appointment to meet with staff at the Odum Institute.

Meanwhile, Seth Murray contacted the archives staff at his home institution, North Carolina State University (NCSU). The project team met there with a digital archivist and their lead librarian for collections stewardship and discovery. They showed us the various services made available to NCSU affiliates, including the consortial scientific data repository, Dryad[12], of which NCSU is a member institution. After exploring options on the NCSU campus itself, the team determined that the most promising home for the NCSU affiliated Historical Ecology data collections will be the consortial Dryad data platform. Similarly, when we circled back to meet with the staff at UNC's Odum Institute, we learned that their consortial repository, DataVerse, will be the appropriate location for UNC affiliated Historical Ecology collections. Dr. Madry is in the process of submitting his digital data into their system. The choice of two large consortial non-disciplinary repositories seems fitting for such an interdisciplinary project.

By leveraging their affiliations with UNC and NCSU, the faculty members will be able to preserve their work without the need to develop their own infrastructure. The institutional commitments to the longevity of the data are sufficient to ensure continued access by themselves and future scholars. While the team will need to develop their workflow for the inventory, packaging, and deposit of materials, they will no longer have to design a replication strategy all on their own or create any storage infrastructure, quite a savings. Though the data will be somewhat arbitrarily divided into subgroups and split between two consortial repositories, we do have ways to unify the whole project collection later, after they achieve the NDSA's Level 1 preservation, using a finding aid to provide an overview and central access to the series in each subgroup.

After inventory, capability assessment, and initial preservation planning, the next step for the team to reach Level 1 is to package their data in its current physical location, with fixity information. This step will ideally precede any significant file transfers and ensure the integrity of files as they are consolidated in one place. The BagIt tool is used to create a folder with the files and a manifest, then this folder is used to create a verifiable ZIP package. These ZIP packages will be uploaded to a shared drive or sent in other ways to a team member who will unpackage them and verify file integrity. If any packaged folders need to be reorganized or pruned before deposit, this is the opportunity to do so. While the verified copies co-exist on the same physical disk they can be moved between packages or combined into larger ones. Generally archivists will try to leave items in their "original order", i.e. in the organizing scheme that they were used or produced. However, in the case of the Burgundy Project, the decades of work may mean that original order needs to be somewhat restored as various partial collections are consolidated from around the world and then split into buckets. Since several scholars have amassed separate digital collections, there are multiple organizing schemes as well, or the schemes may have changed in different eras of the project. Preserving these multiple schemes as they are is fine and may provide valuable insight into legacy tools and workflow. However, if the schemes are nearly the same it may make sense to consolidate them on some level. The downside is that consolidation can result in loss of valuable contextual clues and other information, so a prior check with the original creators is the best policy.

After the buckets and the high-level folders within them have been determined, then the BagIt tool will be used once again to generate fixity information for the new contents. As the buckets are now more or less formulated, we can start referring to them as "archival series", i.e. as the divisions within this archival collection.

For practical storage and delivery reasons, a series may need to span several packages or ZIP files. If you imagine that scholars need to download certain packages on 4G or LTE mobile broadband, then you do well to limit the compressed form of those packages to 3GB or so, since it will take approximately 10 minutes per GB to download the data. If you have certain data that is inherently very large, you can either split a large compressed file into parts that are downloaded separately, or find a repository that offers other delivery options, such as grid or cloud data delivery.

Level 1 Preservation and Beyond

As soon as all the Burgundy materials in the inventory have been safely packaged and transferred to the two consortial repositories, the team can finally take a deep breath, secure in the knowledge that their data is minimally preserved according to the guidelines of the US National Digital Stewardship Alliance. They will have split the data into reasonably sized packages to facilitate access by current and future generations of scholars. They have a main inventory file that describes where all of the data is preserved and its basic composition. Their BagIt packages contain manifests that allow anyone to establish fixity after future transfers. They will have ensured that their files do not contain computer viruses and will have secured any packages that contain sensitive data.

After initial preservation, the next step for the project will be to enhance access to their data by providing a richer description and wayfinding guide for future researchers. In archival practice this is accomplished with a finding aid document, which provides an outline of the entire collection and descriptions of its series and provenance. The finding aids for physical materials might include the shelf, box, folder locations, or other references that help the visitor find or request them. In mixed and digital collections, the finding aids may contain hyperlinks or digital object identifiers that can be used to access the material online. In the case of digitized documents, you may find both a link and a physical location. With their finding aid, the Burgundy team will be able to reunify the series that have been separately preserved at two different consortial repositories. In this same way they may want to incorporate the work of future collaborators, wherever their data is preserved. For future scholars this will provide a single reference point where they can begin their investigations.

Archival Practices and New Projects

It has been a joy to contribute some archival practices to the Burgundy project and it provides an ideal example for how one can tackle a large legacy project. Fortunately newly funded research projects often require a well-documented data management plan that guides stewardship of digital materials from the first byte created. Under the guidance of host institutions, these materials may be steered towards an institutional, consortial, or disciplinary data repository. In these data plan situations the basic metadata layout (or data dictionary) is prescribed and data recorded on an ongoing basis for new materials. The replication strategy and other workflows are thought out in advance and periodically updated. In many cases, a host institution will provide these plans as templates alongside their repository services. Nevertheless, there are many practices that are common to both the planned and unplanned archival scenarios, namely inventory, fixity, transfer, and replication. These practices can be applied at the highest level in a case like the Burgundy project, or on a micro-level whenever an active research project receives a large deposit of new research data, for example from a new colleague with a personal collection they wish to contribute.

Conclusions

In this chapter we have explored the many concerns and practices involved in digital archiving your projects. With a little awareness and preparation, you can set your project on a better path for digital sustainability and longevity. As we know, archaeological excavation is an inherently destructive practice, leaving behind only meticulous records and artifacts that are irreplaceable. Other forms of research, such as collecting historical documents or biological samples, are painstaking and expensive to replicate. Extra care must be taken to preserve the value of all our scientific records, especially in fragile digital form. Not only does digital archiving preserve this record for future science, it enables enhanced collaboration in current projects. By sharing digital scientific records with colleagues we enable a more robust, inclusive, and transparent research practice. Even if you do not become an expert in these digital practices yourself, we hope that you understand their value to your projects and become an advocate for this important role.

References

[1] Richards, J.D., Jakobsson, U., Novák, D., Štular, B. and Wright, H. 2021 Digital Archiving in Archaeology: The State of the Art. Introduction, Internet Archaeology 58. https://doi.org/10.11141/ia.58.23

[2]HTTrack Website Copier (website), https://www.httrack.com/

[3] Levels of Preservation Revisions Working Group, "Levels of Digital Preservation Matrix V2.0," October 2019, https://osf.io/2mkwx/.

[4] https://ndsa.org/publications/levels-of-digital-preservation/

[5] See the website https://alternativeto.net

[6] IETF BagIt 1.0 Internet-Draft, website, https://datatracker.ietf.org/doc/html/draft-kunze-bagit

[7] Python BagIt source code repository, website, https://github.com/LibraryOfCongress/bagit-python

[8] Brunnhilde (Python tool), source repository, https://github.com/tw4l/brunnhilde

[9] ClamAV (anti-virus software), website, https://www.clamav.net/

[10] Siegfried (format identification software), website, https://www.itforarchivists.com/siegfried

[11] Open Preservation Foundation Tools Page (website), https://openpreservation.org/tools

[12] Dryad Data Platform (website), https://datadryad.org/stash

CHAPTER 16

EMERGING TECHNOLOGIES

HISTORICAL ECOLOGY 2.0

SCOTT MADRY

> "The only thing we can be sure of about the future is that it will be absolutely fantastic. So if what I say now seems to you to be very reasonable, then I have failed completely. Only if what I tell you appears absolutely unbelievable, have we any chance of visualizing the future as it will really happen." - Arthur C. Clarke (Clarke 1964)

We live in a time of unprecedented technological change. New developments in computer science and related technologies are creating a new world of massive disruptive innovation. The digital revolution, super computing, quantum computing, daily remote sensing of the planet, big data, smart sensor networks, machine learning, data analytics and more are reshaping our world, disrupting traditional business, academic and methodological approaches, and creating new opportunities for gathering data and our ability to analyze that data in support of our academic interests, including for Historical Ecology. These profound new capabilities are not yet utilized for most applications, but they are on our doorstep, and hold the potential for enabling major innovations in many fields as well as new research directions. This chapter will provide an overview of the disruptive innovations that are emerging, their effects on scholarship and academic culture in general, and their impacts on long-term and multi-participant projects, including Historical Ecology. Let us consider how new and disruptive developments in big data, data analytics, data fusion, in-situ data sensor networks, artificial intelligence, crowdsourcing, citizen science and more could impact the conduct of Historical Ecology projects and potentially revolutionize the types of science conducted.

Disciplinary underpinnings

The disciplinary underpinnings and perspectives are computer science and, in a broader sense, the Silicon Valley entrepreneurial culture of disruptive innovation, rapid technology development, and technological risk-taking. Disruptive innovation is a well-studied process, first described by Prof. Clayton Christensen (Christiansen 1997). It is where a new and novel innovation or technology becomes rapidly adopted and creates a significant disruption in a given market or in society itself. The introduction of the iPhone on June 29, 2007 is an excellent example of this. It simply changed the way people interact with technology on many levels and completely destroyed the existing mobile phone and mobile computer markets and market leaders. It also had a significant cultural impact around the world, where today we simply cannot imagine life without our smartphones in our pockets. There are many other examples of this.

In my 2020 book Disruptive Space Technologies and Innovations: the next chapter (Madry 2020), I present several case studies on how disruptive technological innovation can radically transform not only existing commercial markets and market leaders, but society itself. The disruptive innovation cycle has occurred many times, and the speed and complexity of these changes are accelerating at an ever increasing rate. Examples of a disruptive technology in the past have included mass production of the automobile by Henry Ford, the development of the shipping container and the reordering of global shipping markets, the internet and, more recently, the Apple iPhone. Today most, but not all, of these changes are driven by the extraordinary advances in computing and information technology. Elon Musk and his reusable rockets, Jeff Bezos and Amazon's delivery of nearly anything daily to your door, (which is a database and internet-based business) and the pervasive influence of social media are examples of how traditional commercial markets and social structures are being altered at ever accelerating rates by disruptive technologies. And the spiral continues.

But what does this have to do with Historical Ecology and what exactly do we mean when we discuss these disruptive innovations? Ultimately, the relevant technologies all revolve around computing, digital data, the internet, and global, high speed networking advances. Included in this ever longer list are some things you use today, and some things you have not yet heard of: big computing, big data, data analytics, data mining, data visualization, cloud computing, edge computing, distributed data computing, mobile computing, open source tools, the Internet of things (IOT) and the internet of everything (IOE), in-situ sensor webs, artificial intelligence, machine learning, deep learning, mega satellite constellations for telecommunications and remote sensing, persistent aerial and satellite imagery, citizen science, crowdsourcing, quantum computing, and more. Importantly, these are not separate and individual technologies, but all rapidly intertwine and interconnect, creating a new, digital reality which is rapidly overtaking our world. All of these are, at heart, extensions of computing and networking into every facet of our lives, including the monitoring and measuring of our planet and its changing environment, both now and in the future. We, as individuals, as scholars, and as a society, are ill prepared to digest all of this, and many of its effects are yet unknown. There follows a quick review of what each of these technologies are, at a very basic level.

Big computing

Moore's law, first stated by Silicon Valley computer scientist and Intel co-founder Gordon E. Moore in 1967, generally is interpreted to mean that computing power will double every two years (It's not exactly what he said). This has remained remarkably accurate, to this day.

This massive increase in computing power and reduction in size, without increased cost, is what drives our modern world of smartphones, the internet, and a global digital economy. Transistors made of Silicon, the second most abundant element in the Earth's crust after Oxygen, are the heart of our modern world, and we truly live in the Silicon Age, in the sense of the Stone, Bronze, and Iron Ages of our ancestors. My laptop today is far more powerful, and has more storage, than the most powerful supercomputer on the planet when I first started working, and this process will only continue.

Where are we today? Computers have become very, very fast. The largest and fastest computers today are government-controlled systems dedicated to particle physics and nuclear research. The first petaFLOP computer (capable of one million billion (10^{15}) floating-point operations per second) was developed in 2008, and the U.S. Department of Energy created in 2018 the fastest computer on the planet, which could process 200,000 trillion calculations per second and has over 10 petabytes of memory (1 million gigabytes). It has an

Artificial Intelligence and machine learning-optimized architecture for the analysis of massive datasets, along with an intelligent software architecture, and it cost just over US$200 million. In 2020 the US government announced the first ExaFLOP computer, capable of 1,000 petaflops, or 10^{18} floating point operations per second and costing over US$660 million, and it will have its first 2 exaFLOP system, called El Capitan, installed by 2024 (Smith 2021). These are simply examples of how large and fast computing has become, and Japan and China are constantly vying with the U.S. for the fastest computer crown each year. And all of this flows down to our personal computers and smartphones, which have significant processing power and continue to be more and more capable, and with more storage as well, for about the same price that a very early PC cost twenty years ago.

Big data

The reason for big computers is big data. We live in a world of very big data, and the numbers are staggering. We now live in a truly digital world, and massive amounts of data are generated, stored, analyzed, and shared on a daily basis. In 2012, IBM estimated that we collectively create some 2.5 exabytes (2.5 billion gigabytes) of data each day. For example, Amazon, the world's largest retailer, does not have a single retail store, but operates its business entirely online with over 42 Terabytes of databases serving over 40 million customers around the world each year. They ship over 66,000 products every hour of every day, worth over $400 million in sales each and every day of the year. All of this is done with very big data and very big computing.

Planet, the world's largest commercial satellite data provider (that was just a Silicon Valley start-up a few years ago) has over 40 Petabytes of imagery data available to its customers online, and collects over 3.3 million square km of imagery every day of the year. Google is the unquestioned data king, and is estimated to have as much as 15 exabytes of data, and it processes over 3.5 billion requests each day, processing over 20 petabytes of data daily using over 1.5 million servers operating all day, every day. That is big data, and it is available to us all whenever we want it from wherever we are using high speed wireless internet and our personal laptops and computers, tablets, and smart phones.

Data analytics, data mining, and data visualization

Once we have big computers and big data, we need to be able to analyze and search for patterns and to understand and visualize these patterns in nearly real time. This is the province of data analytics and data mining, which are very big business today and have impacted our world in transportation and logistics, healthcare, weather and severe storm prediction, environmental monitoring, and more. Data analytics itself is so complex, and the data sets are so large and dynamic, that it is, in turn, very much powered by Artificial intelligence (AI) and Machine Learning (ML).

Artificial intelligence (AI), Machine Learning (ML), and deep learning

One of the main limitations of big computing is the requirement to have humans do all the work on the data. People are so much more limited in many ways than machines, with their need for sleep and lunch and vacations and all, and the development of computers that have artificial intelligence and the ability to learn has made possible the analysis of massive databases in a way that humans simply can not do. AI is driving much of the data analytics today, and as machine learning matures, computers are taking over more and more of the data processing tasks. Narrow AI includes existing things like Siri, Alexa, and web bots. AI is already here, with over 100,000 million of Amazon's Alexa systems in use around the world. General AI is quite different, and will, rather soon, have such advanced capabilities that you will not know if you are interacting with a human or a computer. Federated learning is a new concept, used in the medical field, including screening for breast cancer, where data from many different hospitals are mined and analyzed, all the while maintaining the patient confidentiality of each institution and patient. Deep learning is a specific type of machine learning that is designed to use neural networks to more accurately mimic how humans learn and process data, as opposed to more linear and traditional machine learning approaches, as shown in Fig, 16.1.

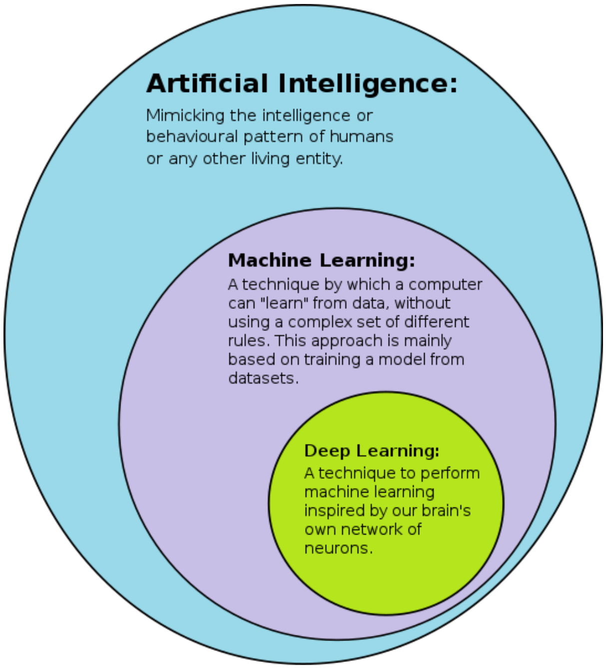


Figure 16.1. The relationship between AI, Machine Learning, and Deep Learning. Image courtesy Wikicommons. https://commons.wikimedia.org/wiki/File:AI-ML-DL.svg

CrowdFlower, Mechanical Turk, and CrowdAI are commercial firms that sell commercial AI services today. These train computers to automatically analyze end users health data, retail sales, transportation networks, and satellite imagery. Many more are being developed.

Cloud computing

Massive data centers are operated around the world by governments, corporations, and even individuals, and the cloud (which is actually just using somebody else's computer over the internet) is very big business, all driven by high bandwidth internet and inexpensive data storage, data analytics, and data processing. Amazon web services (AWS) s the largest cloud data provider today, owning about ⅓ of the cloud, but Apple, Google, Microsoft and many others are also very much involved in this growing business of hosting and processing other people's data. AWS also provides on-demand large-scale virtual computing as well as long-term, secure data storage, AI, machine learning, and broad scale bandwidth, all on a pay-as-you-use model. Big computing, big data storage, AI, and data analytics all go together, and are the integrated engine that drives our modern digital world. This will only become more pervasive.

The Internet of things (IOT), and the internet of everything (IOE)

Traditionally, the internet has connected computers to other computers, and this has been extraordinarily useful, but today, smart devices are popping up everywhere, and this trend is accelerating rapidly, connecting many millions of devices to the web, and this will be a major sea change in how computing is done. Smart TVs, smart cars, smart houses and smart refrigerators that will reorder your favorite foods when you are low, GPS enabled dog collars, and millions and millions of other smart devices are coming soon. These all will be interconnected in a digital web, but they also may bring with them a new reality of 'sensor overload' and there are serious privacy and security issues that will have to be addressed in all of these new digital technologies. But the age of billions of interconnected smart devices, the Internet of Everything (IOE) is fast approaching.

In-situ sensors and sensor webs

One of the most directly applicable emerging technologies to our work includes developments in in-situ sensors and sensor webs, which are a specific type of IOT. Networks of small, low-cost, solar-powered sensors can be seeded throughout a study area that will then collect and send back real-time data of various parameters to be constantly sorted and analyzed. (Teillet, Gauthier and Chicagov 2012). Large city traffic lights are a good example. The integration of microsensors, solar power, low cost computers, and high bandwidth wireless communications has enabled the development of in situ sensor networks for a variety of applications. Water quality and flow sensors, soil parameters, vegetation parameters, solar radiation, all can now be collected remotely using smart sensor webs. Their use is very much in its infancy but shows great promise for our future Historical Ecology work.

Remote sensing was covered in chapter 13, but there are many new and emerging aspects that deserve to be included here. Next generations of remote sensing systems, ranging from inexpensive drones to constellations of thousands of satellites, provide extensive coverage of our planet in a wide range of the spectrum. Today, the company named Planet operates nearly 200 satellites, and they acquire high cadence and high resolution data of every part of the world's land each day, over 300 million square km each day. New, high resolution RADAR satellite systems can acquire imagery at night and through clouds and rain, and new capabilities are available for purchase. LiDAR systems provide detailed terrain data, and High Altitude, Long Operation (HALO) systems are being developed that can loiter over a given area for days or weeks, and there are new concepts for smart systems of integrated aerial and satellite sensors. Improvements are also being made in automated digital image processing and analysis, with systems like the Google Earth Engine that incorporate all of the technologies mentioned above for remote sensing analysis over large areas on a continuing basis much faster than could be done by humans.

Edge computing

Edge computing is a new concept and is, in some ways, the opposite of massive data servers. In this approach, so many computers and smart sensors will be widely distributed, due to the Internet of Everything, that it will become inefficient for all data to be sent to huge data servers for processing. In Edge computing, data are processed as close to the device as possible, at the edges of the net, in a distributed manner, and only processed data, much reduced in size, is passed along as needed, when needed. Edge computing is a more distributed model than massive data centers, and will be driven by the millions of smart devices that will soon be a part of the Internet of Everything. Satellites will soon have onboard data processing, for example, and will download only the processed data required instead of the full stream of raw data. This reduces the amount of data shared, and speeds up the processing as well.

Crowdsourcing and citizen science

Another fascinating paradigm change is the emergence of crowdsourcing and citizen science. Smartphones and more powerful personal computers have made it possible for thousands of people to acquire data in the field and share the information broadly. This has become a powerful new tool for activities ranging from astronomy to birdwatching, and enables regular people, and their computers and smartphones, to be linked together for field investigations and data processing in ways never imagined before, and this will continue to grow in popularity and power. Crowdsourcing has also become an alternate source of funding for academic projects that do not fall into the standard funding processes (like Historical Ecology projects).

Free and Open Source Software (FOSS) tools

The mainstreaming of Open Source software plays an important role in all of this. A new model of freely available and shared source code makes development much faster and more robust. Having many people around the world writing, editing, and improving code alters the digital environment for the better, and even Amazon runs its massive online operations using a collection of Open Source utilities to service their over 40 million customers. This is called the Apache Hadoop Distributed File System. It is a very robust and powerful environment designed for massive data processing and analysis using large numbers of concurrent computers, and includes automatic fault detection and avoidance, and is the engine behind facebook, Yahoo and half of the Fortune 500 corporations today. And it is free and Open Source code available to all completely without cost (IBM 2021). We have covered the many benefits of FOSS tools in GIS and remote sensing in previous chapters.

Synergy and integration

A key aspect of all this is that these are not individual capabilities or tools, but they all meld together into an integrated and very powerful new digital landscape, and this will become more and more so in the future. Synergy will become the rule in data, not the exception.

Historical Ecology 2.0

What on Earth does this have to do with Historical Ecology? You very well may be asking yourself this question. A great deal, I would argue. In the space world currently there is much discussion of 'Space 2.0'. This refers to the radically different way that Elon Musk of SpaceX, Jeff Bezos, Richard Branson and others in what is called the 'NewSpace' community are approaching space activities. This is opposed to the traditional big government and aerospace corporation approach of NASA, ESA, Boeing, Airbus, and other major aerospace corporations. Part of this is generational, but there is also a radically different approach to acceptable risks, goals, rewards, decision making, and organizational structure. Much of this is also very much rooted in the Silicon Valley innovative and entrepreneurial mindset of 'fail early and often', which is radically different from the traditional and very conservative government and corporate approach to large space projects.

Historical Ecology has existed now for some time, and it has been successful in establishing its place among scientific pursuits (Crumley 1994). But it has essentially relied upon the same, original methodological and technological framework since its inception. So what might Historical Ecology 2.0 look like? What if we conceived of a radically different and technologically advanced approach to our work that builds upon and fully integrates these powerful emerging disruptive innovations into our research designs and projects? What might that look like?

Imagine a new Historical Ecology project that is about to be started by a group of recently graduated young researchers. Unwilling to spend the time and energy to submit detailed proposals for traditional grants to funding agencies, the group crowdsources the initial funding required, and begins their work with a jointly conceived research design and work plan, all developed using shared FOSS computing tools. A digital search of remote sensing imagery archives locates several interesting potential study areas, and an automated search for the chosen area of historical data, maps, archival aerial photos and other historical information is quickly conducted in dozens of digital archives and libraries world-wide. A study site is chosen, and an initial drone flight is organized online which automatically collects detailed LiDAR, thermal, and color remote sensing imagery of the chosen study area as initial baseline data. Digital terrain and vegetation data are automatically extracted into the new, cloud-based Open Source project GIS system, and weekly remote sensing data collection is ordered from multiple sources, which is all automatically processed using AI and ML throughout a full yearly vegetation cycle, with appropriate vegetation communities identified and classified for analysis. An AI algorithm decides the best placement of a network of in-situ data sensors, including stream gauges measuring water quality parameters, and ground sensors measuring soil moisture, weather, and relevant vegetation conditions. The sensors are deployed using drones (and also field researchers), and the network is configured using edge computing for the sensor net to collect, process, and transmit their data on a regular schedule for automatic integration with the project GIS, where the results are automatically made available to the team, who receive an email notifying them of each update. Machine learning algorithms automatically monitor the network and watch for unusual patterns in the data. If unusual events are noted, drones are sent to investigate and collect additional images and data, and emails are automatically sent to project participants to go into the field, along with the appropriate GPS coordinates and customized field maps indicating the location and nature of the event to be investigated. A previously unknown historical tax record of the area is discovered in an obscure local library in one of a series of ongoing library searches, but it is hand-written and also partly damaged. Thermal and ultraviolet scanning and digital image processing allows the damaged pages to be read, and a machine learning algorithm is accessed online that, with proper training, is able to decipher the full document. This is then automatically entered into a spreadsheet for analysis and is shared with the group, along with automatically generated metadata. The improved optical character recognition algorithm created is made freely available as Open Source to other researchers world-wide for their use. The automated search for historical maps, aerial photos and documents leads to the downloading of the most interesting data to create a detailed time series, and the smart GIS system automatically georeferences them and extracts individual natural and cultural components representing vegetation and cultural features as new vector or raster GIS files. When each new data set is located and added, it is automatically quality checked, metadata are created, and a new set of statistical analyses, area measurements, and time series visualizations are generated and sent to all project members, including customized data and map representations for each member of the team, depending on their selected preferences and professional interests. A graduate student chooses to run a new image processing analysis on several satellite images, similar to that done in a recently published paper that was sent to him based on his research interests. This is done, all by using a natural language interface that does not require specific software familiarity or programming skills. Artificial intelligence and machine learning processes find new relationships between disparate datasets, and create new spatial and temporal models. It also refines existing approaches as new data are available or new publications suggest new ideas or hypotheses that could be tested. Data can be reanalyzed and project results can be compared with other, similar projects in similar environments using their methods and approaches, and multiple projects in different locations can also be compared over space and time. Field data, including sensors and ground photos, are collected and automatically sent to the centralized project cloud computer system for mapping and archiving, and metadata are automatically extracted from new data and updated as data are analyzed and new layers are created. The project's advanced digital archiving system automatically searches for, scans, and sorts new data as it comes in and feeds it into the project's digital archiving system, and alerts project members when new photos, recordings, old postcards, or other data are located on the web, based on their specific interests. Project members can easily access all data in all formats by location, keyword, data type, or natural language customized searches, and customized maps or atlases can be generated digitally or on paper on request by team members. Relevant new journal and conference papers in each discipline are automatically searched for and downloaded, analyzed, summarized, and sent to project members and sorted for archiving by keywords, location, and other factors. Individual journal formats, including graphics and citation formats, are automatically generated for use on demand for authoring new publications or proposals in as timely a manner as possible. Complex final graphics, statistics, and charts are generated quickly using a natural language voice interface.

Conclusions

All this may sound ridiculous, or even impossible, but it will surely happen, and much faster than you might think. So what is left for us humans to do? By managing all of the very time consuming and tedious 'grunt work' usually associated with such complex research projects, we humans will be free to focus more on the real problems of interest: theoretical questions, methodological advances, and the analysis of ever more complex problems over space and time. We can also study ever larger areas and do more comparative analysis between multiple study sites or with other comparable research programs. Historical Ecology research is inherently transdisciplinary, and we are interested in the analysis of multiple, interconnected threads of environment, climate, ecology, geology, society, economics, politics, markets, technologies, and more. The emerging digital capabilities briefly presented in this chapter will serve a very real purpose by allowing the analysis of levels of complexity well beyond the ability of a single researcher or even a large team at the present time. The ability to collect, store, analyze, and visualize massive amounts of disparate data may very well allow us to attain new levels of understanding, and move Historical Ecology research into a new and fruitful era not possible with today's technologies, data, and methods. New questions may be posed and answered, new areas studied in detail, new ideas can be tested, and new concepts pursued.

Epilogue

Presented above is a consideration of how technology is rapidly advancing and how this will almost certainly impact how we conduct Historical Ecology Research. It was intended to be an eye-opening read to many of our more traditional colleagues in the field. But we know that Historical Ecology research is very dialectical in nature, and there is another side to this technology coin that must also be considered at the same time. Anyone who has done this type of intensive and long-term work knows that there is a very human side of the equation. It is not all statistics and pixels. We all establish a deep and personal relationship with our study area, its people, and the maps and dusty documents that become important aspects of our lives. Years ago we did a paper on improving the accuracy of digitizing historical maps, and presented it at one of the leading computer and archaeology annual conferences (Computer Applications in Archaeology- https://caa-international.org). After my presentation, several colleagues asked me "why don't we just develop entirely automated tools to do this?" and we replied, quite emphatically, that we would never want to do this. We love our old maps, and spend wonderful hours pouring over them, studying each ragged corner, wondering what a given feature represents, and trying to get into the minds of the cartographers who created them and hoping to see in our mind's eye the now-altered landscapes that they represent. We would never want to simply have a completely automated process that takes us, the human mind and heart, out of the equation. And it is the same in the field. All the satellite images ever collected do not replicate the knowledge (and joy) that we draw from walking through the fields and woods in our study area, finding a new small indicator of some previous land use, or a fragment of a long-abandoned roadway that we didn't know existed. It is much more, of course, than a study area, it is a place that we love and find fascinating and there is no technology that can replicate the personal connections or insights that are developed by simply being there. An important aspect of how we will have to adapt our work in the future is not only how we will integrate the tidal wave of technologies that are engulfing us into our future work, but how we must find ways to keep the human aspect, the human touch, and the human connection in our work. Nothing replaces connecting directly with the landscapes and places in person, and the bits and bytes need to be in support of our very human intellectual endeavors, and not become replacements for them.

As Arthur C. Clarke said:

> "The Information Age offers much to mankind, and I would like to think that we will rise to the challenges it presents. But it is vital to remember that information – in the sense of raw data – is not knowledge, that knowledge is not wisdom, and that wisdom is not foresight. But information is the first essential step to all of these." (Clarke 2003).

These advances discussed above, and even more emerging technologies that are on the horizon, have the potential to ultimately create a new Historical Ecology 2.0 paradigm, one that will be able to address questions we are currently unable to fathom, and which will bring us much closer to the knowledge, wisdom and foresight that we seek in our quest to understand the relationships of people and their environments over time. It is now time to begin to make this a reality. We must begin by starting to harness these capabilities and to use these new tools, in concert with our traditional and very human actions, in our work today to the extent now possible, and to seek the participation of experts in these new technologies in our projects. Let us begin to take baby steps towards Historical Ecology 2.0, but let us also keep what we do a very human endeavor. Finding that balance will be our task.

References

Christensen, Clayton M. 1997 The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. [Boston, Mass.]: Harvard Business School Press, 1997.

Clarke, Arthur C. 1964. BBC's "Horizon": https://interestingengineering.com/video/arthur-c-clarke-made-a-scarily-accurate-prediction-of-the-future-in-1964

Clarke, Arthur C. 2003. As quoted in "Humanity will survive information deluge - Sir Arthur C. Clarke" in OneWorld South Asia (5 December 2003).

Crumley, Carole L. 1994. Historical Ecology: A Multidimensional Ecological Orientation. In Historical Ecology: Cultural Knowledge and Changing Landscapes, ed. C.L. Crumley, pp. 1-16. Santa Fe: School of American Research Press.

IBM.com 2021. What is the Hadoop Distributed File System (HDFS)?". IBM. Retrieved 12 November, 2021.

Madry, Scott 2020. Disruptive Space Technologies and Innovations: The Next Chapter Springer Nature, Switzerland. 252 pages.

Smith, Ryan. 2021. "El Capitan Supercomputer Detailed: AMD CPUs & GPUs To Drive 2 Exaflops of Compute". www.anandtech.com.

Teillet, P.M., R.P. Gauthier, and A. Chichagov 2012. Towards Integrated Earth Sensing: The Role of In Situ Sensing. In: First International Workshop on Future Intelligent Earth Observing Satellites (FIEOS) May, 2012.

SECTION 5

INTEGRATION AND CONCLUSIONS

This section presents three concluding chapters which deal with how we integrate and manage all of the disciplinary perspectives and data presented in the previous chapters. Historical Ecology is unique in the pivotal importance of its interdisciplinary focus and perspective. It is inherently about how we take all of the pieces presented here (and many more) and find ways to actually integrate these into a whole which is greater than its individual parts. Chapter 17 presents some thoughts about how we can actually integrate the various data and perspectives, as well as how we can actually manage such complex projects over time in a practical manner. Chapter 18 looks at the fine art of human collaboration and how we can successfully find ways to work together across the deep cultural and disciplinary realities that divide us. Getting people to work together productively is always more difficult than managing data, and we consider how this can be done because, in the end, if we cannot find ways to work together across disciplines and cultures, there can be no Historical Ecology research. Finally, Chapter 19 presents some final conclusions and thoughts about what we have presented in this volume, what it all means, and where it is all going.

CHAPTER 17

PLANNING, DESIGNING, AND MANAGING A HISTORICAL ECOLOGY PROJECT

SCOTT MADRY AND ELIZABETH JONES

In the several previous chapters, we addressed a sampling of individual disciplinary perspectives, approaches, techniques, and datasets that can contribute to the complex understandings produced by Historical Ecology research. There are many others that could have been included, but that will have to wait for the second edition.

We now consider how to operationalize the integration, analysis, and production of research results combining these many very different disciplinary lines of work into a coherent whole.

In this chapter, we consider the practical issues of planning, designing and managing a Historical Ecology project, from conception to completion. What is described has much in common with any research project, but there are also specific aspects that must be considered in a Historical Ecology project, which may draw from several analytical methods, theoretical frameworks, and multi-disciplinary collaborative research. The topic is approached in the framework of creating and implementing a research design. We will use this structure to address the different aspects of quantitative and qualitative data, inductive and deductive reasoning and approaches, the processing and analysis of data and data variables, structuring your analysis, managing and tracking your work, and presenting your results. Then, some practical suggestions and best practices relating to how to functionally integrate the various data types and formats that cross traditional disciplinary boundaries and that advance the practice of Historical Ecology will be presented. All with a goal to operationalize your research and to be able to work efficiently and productively in a collaboration with researchers from varied backgrounds using different methods and data. The following chapter will consider the closely related topic of collaboration in such a project with researchers from other disciplines and academic cultures.

Introduction

Historical Ecology research addresses fundamental questions about the relationships between humans and human societies and the environments in which they live, across both space and time. Our interests span the theoretical, methodological, and practical aspects of this work, but somehow, we have to put these all together in a manageable way, as people working together in the real world. This chapter will consider these practical aspects of integrating the several subjects presented in the previous chapters into a workable and manageable program of work that delivers usable results. Very few of us had the luxury of having formal instruction in this, and we all learned how to do this on our own, through trial and error in our own projects, including lengthy discussions with colleagues from other disciplinary backgrounds. We hope that this volume will be a step forward in this important topic.

Research design

All groups considering conducting Historical Ecology research should give thought to their research design before they begin their work together. A research design is just a plan, as detailed as possible, but still just a plan. It should lay out the broad goals, methods, timelines, and desired results of the work to be conducted. These can be, and should be, living documents shared online, and evolving as the work is done. Often, the framework can be extracted from a successful grant or dissertation proposal, but we must note that Historical Ecology work is inherently interdisciplinary, and no single dissertation within a single discipline is up to the task. There is no single right way to do this, and different disciplines have very different approaches, but it is better to start somewhere than to skip this step in the research process. It will be something to come back to, and refine along the way. In a collaborative project, it is important that the research design is developed in interactive discussions between all participants in the group. A research design document can be broken down into some of the following components (yours may be different):

- General research problem or issue, mission statement, and goals/outputs.
- Overarching theoretical approaches and theoretical context.
- Basic questions to be addressed, hypotheses to be tested, and how results will illuminate the research problem or issue.
- Methods and techniques to be used to address the research questions.
- Data to be used in your analysis: including historical population and land use data, property ownership, births and deaths, species data, field work, ethnographic interviews, library research, archaeological excavation, field ecology work, GIS, remote sensing, GPS, etc. This includes primary data you will collect as well as secondary data located in archives or libraries or in online archives.
- Data analysis design: the specific process of how the data will be collected, processed, and analyzed, shared, and integrated.
- Data management plan, naming conventions, security, backups, physical and digital data archiving, etc.
- Desired final products, reports, publications, presentations, websites, social media, etc.
- Project management tools and approach: Gantt charts, timelines, budgets and financials, contact info, websites, participation agreements, human subjects, etc.
- Participants, roles and responsibilities

We will consider each of these in turn, but it should be noted that there is no firm or required format or structure for your research design. It will vary significantly between a single summer field project, an individual's thesis proposal, and a large funded, multi-institution, multi-year field research program. The overall goal is to think through all the issues before you commit to begin the work, and to identify potential problems, single point failures, and other issues as early as possible and to keep them in mind. You then use the plan to track your progress and expenses as the work unfolds. As stated, this should be a living document which is shared, revisited, and updated, and which evolves as your work progresses. There is a link below in the references to a very good example and general guide for how to do this that includes many useful definitions and additional information, all presented at a basic level (Scribbr 2021a).

General research problem/issue and a mission statement

What are your overall research goals and how do you intend to achieve them? This should be the first item that you address. What is your purpose? What do you want to achieve? Specifically, how will this research contribute to understanding an issue, solving a problem or filling a knowledge gap related to Historical Ecology? And what are the means through which the research will be carried out? For example, is it a one field season summer project with a few participants producing a single paper, or a longer-term, major research program? How will the results be disseminated and what is the expected impact of the research results?

Mission Statement

A mission statement is a succinct statement of overall objectives. It can be helpful to try to write a simple and direct mission statement of what you intend to do, and the shorter the better. In President John F. Kennedy's speech before Congress on May 25, 1961, he stated that the United States "should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth." (John F. Kennedy Center 2019) This is an excellent mission statement. It is a very brief and direct statement with clear goals and a fixed completion date. The Apollo project that this simple statement launched ended up including over 500,000 workers and spent some US$26 billion over 13 years (equal to some $257 billion today), but this initial mission statement was simple, clear and direct. A simple mission statement of what you intend to achieve can help you to agree on what you will do before you start, and it can help you decide, down the road, what is on the critical path and what is not, when priorities must be reconsidered as funding, staff, and other circumstances change.

What might a mission statement for a Historical Ecology project look like? It is complicated, as there may be many people involved with different perspectives and approaches. But it is worth trying to consider as a group. What are we trying to do here? It is common that people come in with different ideas of what is important or needs to be done. Perhaps there could be one overall mission statement and then there could be several subcomponents that are linked together.

Study Area

Another key component of your research design is the study area location, dimensions, spatial scale and granularity of analysis. Will you do a very detailed analysis of one or more small defined study areas, or cover a larger area at a moderate granularity? We often employ nested focused study sites for more detailed analysis that are used to inform the larger project area, but all this should be considered before you begin. Equally importantly, what are the temporal dimensions of the project? How far back do you intend to look in time, and at what frequency? The differing types of data sets available will most likely span overlapping but differing time periods and spatial ranges and will have differing degrees of temporal and spatial resolution. Choosing the temporal and spatial dimensions that will facilitate integration of the various data sets, while still adequately providing information that speaks to the overarching research questions will be a key factor in determining the spatial dimensions and times scales of the project. Similar boundaries can be placed around the timeframe of your work and an assumed completion date. "We intend to conduct X work in Y area over Z timeframe".

Theoretical approaches and theoretical context and goals

What are the disciplinary and interdisciplinary theoretical frameworks, including Historical Ecology but not limited to it, that will guide and inform the work? Do you intend to test and advance theoretical approaches, or rely upon one or more methodological perspectives to guide your work? Is there a specific focus on advancing theory, or will you rely upon established theoretical foundations as a base from which to work? One of several theoretical approaches, as described in Chapter one, can be used. For example, Marxist theory of farm labor, markets, and production. There are others as well, associated with all the different disciplines that are within the larger Historical Ecology umbrella.

Basic questions to be addressed, hypotheses to be tested, and desired research goals

Having stated your overall, higher-level goals, next you might consider what are the issues that you intend to directly study and how you plan to go about implementing the higher level goals stated previously. This takes your project design to the next level of detail and should present your several specific research questions, hypotheses, and desired results.

This is where you begin to weave the complex fabric of the disciplinary, interdisciplinary, and transdisciplinary work that you will undertake. You should state what the research questions are that you intend to address, and what analysis you will do, and what knowledge you will generate. Here you will begin to conceptualize the various parts of your project, and, importantly, how they will all fit together into a single entity with integrated results. Historical Ecology work is different from most disciplinary and even interdisciplinary activities, in that in many other projects, researchers take either a generally quantitative or qualitative approach. But we inherently do both (and more), which is rewarding but also complicates the planning and work. The physical and natural sciences tend to work in and think in terms of quantitative data and research designs, as described in several of the chapters above. They measure environmental or chemical or other discrete variables and use these data to test specific hypotheses or to conduct experiments that can be replicated by others. The social sciences and the humanities tend to work in a much more qualitative sense, dealing with humans and their writings, ideas and social fabric. Ethnographic, historical studies, and similar scholars work in words and not so much in numbers, and they approach their work in a different way, also described in the chapters above. One of our goals is to bring these together in meaningful ways that further our research goals and plan. How are you actually going to do this?

One way is to specifically lay out the methodological approaches to be used for each aspect of your project. Quantitative and qualitative scholars approach their work differently, but we can aim to integrate these. Much has been written about the differences between inductive and deductive research paradigms and approaches, data, and results, and we will not cover all of that here, but it should be noted that physical science and environmental science work is usually done using quantitative data and deductive approaches, with specific variables and data processing approaches. You can set up experiments, describe what you observe, including patterns and relationships, and create and test hypotheses that can be replicated by others using the same methods. Historians and those in the social sciences tend to use more inductive approaches, which are less rigorous in one sense, but which follow their own rules of evidence and validation, as described above. They seek to discern patterns and relationships, some aspects of which are expressed in non-quantitative terms, such as the phenomenological, the emotive attachments and sociocultural meanings of lived experience. These aspects are of great importance in understanding human's relationships with their environment. Of course, historians and social scientists also deal with many kinds of quantitative data and can offer good models of integrating the quantitative with the qualitative. Will you be conducting archival research, ethnography, or case studies? How will the data be collected, analyzed, and managed in a way that allows integration or linking with the deductive approach and quantitative data of the earth sciences? Part of the goal of Historical Ecology is to merge and cross-pollinate between these, and you should consider this up front.

Literature Review

Reviewing existing projects and their approaches and results can help guide you, so conduct a literature review, including the most recent results, and see what others are doing and what makes sense for what you want to do and how to go about it. Nothing works well in a vacuum, so make sure that you are aware of the work of others, how it was done, what the state of the practice is, and how you can use this to inform your work and advance the state of knowledge.

Methods and approaches to be used to address the research questions

In this section, lay out the several disciplinary methods and approaches that you will use, both individually and, later, in an integrated manner. If you have an anthropologist, ecologist, geologist, historian, and GIS-fluent geographer, what can their skills and toolboxes bring to the project, and how will they fit into the larger, overall research design? Once you have described the data and methods to be used for each individual researcher (or team), it is then easier to figure out ways in which all the research can fit together. The results produced by the various data sets and analyses can be used for independent cross-checks on each other, that can call interpretations into question when they differ, or validate each other when they agree. Almost always these independent lines of investigation when brought together enhance our understanding of both the individual aspects of human-environment relationship as well the functioning of the complex whole.

Data to be used

Once you have defined what your research goals and methods are, what disciplinary perspectives will be used, what theories or hypotheses you want to test, and what the spatial and temporal extent of your study area will be, you should define what data you will need to be able to address your various research questions. Each qualitative research question or quantitative hypothesis to be tested will require its own combination of data and data analysis, including a combination of new data generated by field work and existing or archival data. Which data to use can and should evolve over the course of your work. Sometimes new data can be found that will allow you to address additional questions not originally defined, while conversely, sometimes you are not able to find the data required to address some of the initial questions that you wanted to consider. In this case, you have to reassess your research questions so that they match your available data and data processing capabilities. This is an iterative process (Madry, 2021), but you should define up front what data you intend to acquire or create that will allow you to address each individual research question or hypothesis, as well as your overall research design goals. Match your research questions with the data needed, and address how you will go about both acquiring the data and analyzing it to do the work that you plan.

Data can be thought about in several ways, as qualitative vs. quantitative data, primary vs. secondary data, descriptive vs. experimental data, among many others. Primary data are what you collect yourself, where secondary data are previously collected data sets such as governmental records or existing modern GIS data downloaded from a commercial or government server. You can design your own primary data to get exactly what you want, but it is costly and time consuming. Secondary data are more often quickly available, and often available for free or limited cost, but you have no control over the structure or format. A consideration up front of all of these types of data can provide some new insight into the work ahead. A quick statement of which types of data are already on hand, what will be acquired from libraries or commercial sources, and what will need to be collected in the field should be described. Known sources of data should be identified, along with the costs of the data or travel and fieldwork required.

Data biases, errors, and limitations

You might also give some thought to the likely or potential biases or other limitations in your data, as these are inevitable and an up-front assessment of these is useful. Data errors and the likelihood of error propagation could also be addressed.

Documenting and tracking your data

There are several ways to categorize your data, including data currently available or on hand, data still to be found, archival data sources, data sets from previous studies related to your own research questions, newly created data from field work, excavation, ethnographic interviews, GIS analyses, remote sensing, and GPS, data from available sources, such as paying commercial firms or governmental agencies for specific data, etc. A simple Excel chart with all your data by project user or use type (GIS vs. ecological field data) may be a useful way to lay this out, and this will allow you to track the acquisition and later analysis of your data. This will also be helpful in your digital archiving process. These research projects can generate a great deal of data and managing it all, what it is called, its metadata, where it is, and what were the original sources, where it is stored, backup strategies, etc. can be a large job, even overwhelming in large projects. Make a data outline up front and match your data to your research questions as early as possible.

Field Data collection

Field data You should define the field work to be conducted, methods to be used, and data to be collected. This should include a description of the field work, field forms and field data descriptions, etc. Will you use paper field forms, electronic data records, or a combination of both? Approximately how many field workdays and how many people will be involved? What will the approximate costs be and where do these funds come from?

Archival data Your plan for archival research should be put here, which libraries or archives will you visit, how many people for how long, travel costs, online access, copyright issues, etc.

Data analysis design

Once you define the data you will have or need, you should consider the analysis to be conducted. In this section, you should present how you plan to process the various raw data that you have identified and acquired into usable intermediate products for analysis. This includes initial quality control (often referred to as QA/QC or Quality Assurance and Quality Control) of all data. Both the digital data that you generate yourself and data that you acquire from archives or other sources should be checked before being cleared for use on your project. Remember the old saying of "Garbage In - Garbage Out". Proper metadata (data about the data) should be created and regularly updated as work is conducted. Flow charts are a very useful tool to help visualize and define this process (Figure 17.1).

Next, if you are using computer software to manipulate and analyze data such as GIS for spatial data or ATLAS.ti for qualitative data, you should consider what processes will be required for the initial recategorization and reclassification of individual data sets into useful categories and what manipulation will be required for importing the data into the software. This is essential preparation of the data for any final analysis that incorporates multiple sources such as aerial photos and remote sensing, GNSS, field work, historical maps, and other sources in a GIS.

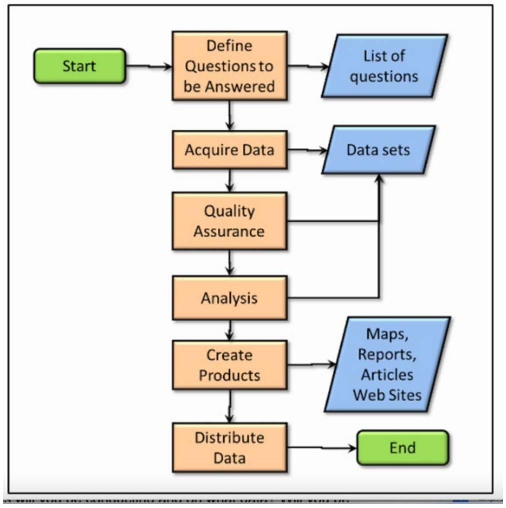


Figure 17.1. A flow chart of the data analysis process. Image courtesy Cal Poly Humboldt University. http://gsp.humboldt.edu/olm/Lessons/GIS/06%20Vector%20Analysis%20Attributes/00_SpatialAnalysis.html

This involves an understanding of the differing data types and variables, and the biases inherent within them. For quantitative data you may wish to develop testable hypotheses that require specific independent and dependent variables. You should consider the issue of data biases and what inferences or conclusions you can reach with what data and with what confidence. What statistical analyses will you be conducting and on what data? Will you be conducting simple descriptive statistics of the land use and land cover of the research area over time, or will you use more complex statistical analysis approaches or GIS predictive models or hydrological models? Will you need to develop inferential statistics where data are lacking?

You can use the same flow chart concept to describe in more detail the specific intermediate and final data analysis processes for your data (Figure 17.2). This is often done for GIS and remote sensing data analysis. This example was done by a Cal Poly Humboldt University GIS student project, as a part of a larger water resources project along the Klamath river in northern California.

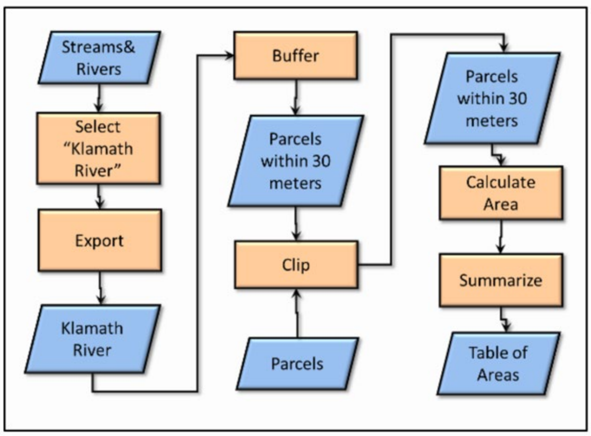


Figure 17.2. A more detailed flow chart of the data analysis process for a specific GIS task. Image courtesy Cal Poly Humboldt University.

http://gsp.humboldt.edu/olm/Lessons/GIS/06%20Vector%20Analysis%20Attributes/00_SpatialAnalysis.html

Even if these data analysis processes change as you go along, and they may, laying out a plan of what data you need and how you will do the analysis helps you in many ways to begin to organize, track, and complete the data analysis aspects of your project. It is also the first step in your digital archiving process.

Data management

You will need to have a plan to manage and archive your data both physical and digital, and this section presents the data management aspects of your project. Several funding agencies require detailed, specific data management, curation, and archiving plans in your proposal, and reporting on a specific schedule. You should include items such as standardized data naming conventions, data security, backup schedules and off-site backups, data versioning, long-term data archiving (Chapter 15), and related frameworks for your project data of all types. How do you intend to implement this aspect of the work? Will each participant be responsible for their own data? Having a data management guide online and available to all provides a quick reference guide for all project participants. In many projects, the shared GIS database serves an important role in all this, as a repository, place for analysis, and archiving of data long-term, but this may not be the case for you.

Data archiving

Both during and after your project, how will the data be stored and archived. What happens to the data when people graduate or leave the project, or when the project is completed? This includes both digital and physical data, including papers, documents, field samples, archaeological artifacts, pollen data, ecological and geological samples, etc. How will you manage the long-term curation, storage, and preservation of all of these? Who owns all of this, who will have access, and where will it all live? This includes the basic question of who owns which data, and also the important question of human subjects data. Will any of your data and results be considered sensitive or restricted data? Will you use data that you have permission to use but not share?

Reporting and Dissemination of Research Results

You should have a general plan for the final results and products. This includes desired final results and final products, reports, publications, presentations, websites, social media, etc. What are the final goals of all this work and how will you present your results? You should develop some shared understanding of what your final results should be, so that all the intermediate work described above all has a goal and purpose. Are the overall goals to write a multi-author book, submit peer-review journal articles to specific journals, create and manage a project website, maintain social media sites, complete a Ph.D., etc. What is the timeframe of each of these, and how do they interrelate? For each, what are your final data deliverables? What types of images, charts, maps, tables, and visualizations will need to be produced and in what timeframe?

Participants, roles and responsibilities

In this section, you should outline who will play what roles in your project, with the understanding that these roles can and do change. Who will take the initial leads as Principal Investigator (P.I.), who will be co investigators (co-I's), data managers, field work managers, etc. For your final results, who will be the lead on the various papers or conference presentations? We also discuss this in the following chapter. A realistic view of how much time each person can work on the project and how that will change is vital for everyone to understand before you begin. This topic is also covered in more detail in the following chapter, but you should include information about the people and their roles in your work plan. Having participants clearly understand their role regarding analysis, field work, library research, etc. helps to avoid problems later on, and we address some of these human issues in the following chapter. Often, people wear several hats that change over time, and that is fine. We like to rotate who is the corresponding author for publications, so everyone gets to wear that hat in turn, particularly when the topic is close to their expertise. As stated in chapter 18, different participants will have different needs, timelines, publication goals and availability, and these should be considered up front and incorporated into your planning process.

Ethics and ethical issues are important aspects of all modern, collaborative research. An understanding beforehand of what are the requirements to be listed as a co-author, or be acknowledged, and the order of authors should be clearly laid out. You may want to have all project participants read and sign ethics forms, stating clearly the ethical requirements regarding issues including plagiarism, ownership and mismanagement of data, falsification of results, conflicts of interest, and improper academic, personal, and financial conduct. Sadly, these are becoming a common requirement of modern research projects.

Also to be addressed are human subjects and Institutional Research Board (IRB) permissions, and other permits required for your work. These can include permits for field work, archaeological excavation and survey permits, permitted for getting field samples out of/into different countries, access to recent census and demographic and other data. These all need to be coordinated well in advance and vary greatly county by country.

Project management tools and approaches: Gantt charts, timelines, budgets and financials, contact info, websites, etc.

You should develop and place your project management plan here. How will you track the project work progress and budget? Will you use Google Docs, MS Teams, or other shared collaborative environments, or have one person keep it all in Excel spreadsheets? State how you will track the work, data processing and analysis, funds expended, and timelines and project milestones. Who will be responsible for updating and reporting these milestones and on what schedule? It could be that each participant does their own, or it could be a dedicated individual or team. Who will be responsible for these administrative aspects of the project work, including updating Gantt charts, budgets, and work deadlines and submitting required reporting to funding agencies? Include here how and how often you will hold in-person or virtual project meetings and how you will manage meeting notes, to-do items, reimbursements, etc.

Will you have a project computing approach, and will you use each individual's own computers and software, dedicated data servers, use the cloud, or a hybrid? You should also consider what tools you will use. For example, will you do all your GIS using a common platform like QGIS or ArcGIS, or will each researcher be free to use tools of their choice? If so, how will you share and store the data and deal with data format issues and versioning? Will dedicated computer hard drives be purchased or will each person be responsible for their own data during the project and for archiving after?

Limitations

There are certainly limitations as well as benefits of working in this way. Creating a research design plan before you begin working may seem to be a major project in itself and not worth the time or effort required, but creating even a skeletal framework of a research design makes a big difference in defining your project, schedule, data needed, data processing, and in setting expectations, requirements, and goals for all the participants in a new project. Even doing a first order overview of these issues will be helpful. Of course, it all can change as the project progresses, but creating such a research design will help you define, track and manage the complexity of the work and budget, and let you see when particular aspects of the work are behind schedule or over budget.

All of this takes time, time not spent on the actual project work, and it is therefore easy not to properly consider project design and management. We want to just start doing the work! But it is time well spent, and the larger the project and budget, and the longer the project time frame, the more project design and project management will be required. Once you prepare one research design it is easier to adapt or refine it and it can be the basis for future grant proposals as well. Including aspects of a well thought-out research design can enhance your funding proposal and impress funding agencies that you have thought through these issues and have a plan for moving forward.

Examples from other projects

There have been many books and papers on scientific research design, usually from either a quantitative or qualitative perspective (Abbot and Martin 2019, Creswell 2009). There are also multiple papers discussing research design from the various individual disciplines that participate in Historical Ecology such as archaeology (Halpern 1998) GIS (Steinberg and Steinberg 2015), and ecology (Michener 2008). But there are fewer references addressing research design specifically in Historical Ecology, and its specific characteristics of incorporating various quantitative and qualitative data. There have been some articles on this subject that specifically relate to these types of projects (Eriksson et al. 2021, Lindholm & Ekblom 2019, Lindholm et al. 2015). There are examples of other Historical Ecology research projects addressing these issues. For example, Santana-Cordero and Szabó address these issues with a review of data analysis and methods in Historical Ecology working with qualitative and graphics data (Santana-Cordero and Szabó 2019). But there is certainly room for additional work in this regard, so share what you do and what you learn with the larger community.

Research questions should be openly developed and iterated, with a goal to find aspects that are relevant to as many participants as possible. Some work will be inherently stovepiped, but finding these cross-cutting questions will fuel the discovery process. Finding ways for different researchers to address similar questions with their own methods and data builds a strong crosscurrent of collaboration. Describe the questions that can be addressed by individuals with their particular data sets, using the methods and standards of their own particular discipline, before turning to the more integrative aspects of your work. One aspect of this is that this requires that all of the participants need to learn something about each other's approaches, data, analysis, and results. What can each person or group generate, how reliable is it, and how does it relate to my work and our overall goals? In this context, the Burgundy Landscapes Working Group develops guiding overall questions at multi-day, face-to-face meetings that begin with everyone presenting their own data, analysis, and perspective, all followed by general questions and discussion. After everyone has presented, we have general discussions and brainstorming to consider commonalities, sharing data, and possible new research questions. 'Show and tell' brainstorming events are very useful.

Conclusions

The complex spatial and temporal phenomena that are the subjects of landscape studies and Historical Ecology research require many data types and data analysis techniques. The development and use of a comprehensive research design plays many useful roles in this context. Our recommendation is to spend the time to create a research framework for your project and to use it to track your work and financial progress as your project progresses. It can start as a simple skeletal framework and be filled in as you proceed, but try to do this, make it a part of your daily work process, and do please share your lessons learned, best methods, and suggestions for others to advance the state of the practice, as we have tried to do here. Help others to follow you.

The next chapter will deal with the closely related but even more complex topic of how we can collaborate effectively in these sorts of projects. Managing people and teams across disciplinary barriers is a vital and difficult part of this work, and we will consider how to do this next.

References

Abbott, M. and J. McKinney Understanding and applying research design. 2013. John WIley & Sons.
Creswell, John W. Research design: Qualitative, quantitative. and mixed methods approaches -3rd ed. Sage Publications 2009

Eriksson, O., Arnell, M., & Lindholm, K. J. 2021. Historical Ecology of Scandinavian Infield Systems. Sustainability 2021, 13, 817.

Halpern, B. 1998. Research Design in Archaeology: The Interdisciplinary Perspective Near Eastern Archaeology Volume 61, number 1 March 1998.

John F. Kennedy Center 2019. https://www.kennedy-center.org/video/center/discussionspoken-word/2019/president-john-f.-kennedy-speech-to-congress-on-space-exploration/

Lindholm, K. J., von Hackwitz, K., Ekblom, A., & Löwenborg, D. 2015. Rethinking human nature: bridging the 'gap through landscape analysis and Geographical Information Systems (GIS). eTopoi. Journal for Ancient Studies, 1.

Lindholm, K. J., & Ekblom, A. 2019. A framework for exploring and managing biocultural heritage. Anthropocene, 25, 100195.

Madry, S. 2021. An Introduction to the QGIS Open Source Geographic Information System. Chapter 13, pp. 207-208. Locate Press. https://locatepress.com/book/itq

Michener, W. 2008. Quantitatively Evaluating Restoration Experiments: Research Design, Statistical Analysis, and Data Management Considerations. Restoration Ecology June, 2008.

Scribbr, 2021a. Research Design

https://www.scribbr.com/methodology/research-design/ Accessed September 11, 2022

Scribbr, 2021b. An Introduction to research methods

https://www.scribbr.com/category/methodology/ Accessed September 11, 2022

Santana-Cordero AM, Szabó P. 2019. Exploring Qualitative Methods of Historical Ecology and Their Links With Qualitative Research. International Journal of Qualitative Methods. January 2019. doi:10.1177/1609406919872112

Steinberg, S. and S. Steinberg 2015. GIS research methods: Incorporating spatial perspectives. ESRI Press.

Szabo, P. 2015. Historical Ecology: Past, present and future. Biological Reviews, 90, 997–1014.

CHAPTER 18

THE FINE ART OF COLLABORATION ACROSS DISCIPLINES AND CULTURES

SCOTT MADRY

This chapter will consider the difficult issues regarding people collaborating and working across disciplinary, national, and cultural boundaries. Here we will consider what collaboration is, and also how these complex differences are fundamental in both fostering and inhibiting successful collaborations that cross all of these traditional boundaries. We will present practical suggestions regarding how to create and sustain a complex project consisting of many researchers from different regions, disciplines, and backgrounds.

Introduction

In the previous chapter we considered the use of a research design to structure the planning and management of your project in terms of timelines, deliverables, data, and budgets. We now turn to the much more complex subject of people. Data can be structured and managed, but people must be collaborated with, and people are so much more complex than numbers, maps, and spreadsheets. We all know that working together is difficult, even within our own national cultures and disciplines, but working successfully beyond our local contexts can be much more difficult, if also much more rewarding, and the inherent nature of Historical Ecology work requires us to do exactly this. But how can we learn how to do this? Where do you start? What can we do in a practical manner to learn how to succeed in this?

We have previously considered this very issue in this context (Jones et al. 2017) as have several others (Marzano et al. 2006, Baldwin and Chang 2007), and yet, this is often the most difficult and problematic aspect of collaborative work. So how can you approach this topic? We propose a consideration of this from a cultural and anthropological perspective.

Cultures and subcultures

First of all, we must be aware that human cultures and subcultures are vastly different and that we each come equipped with our own, invisible cultural bubble, formed and elaborated since birth. The study of culture is a fundamental aspect of the discipline of anthropology, and much has been written and studied about human culture and its powerful yet invisible role in our lives (Madry 2024).

Not only are we all born into the invisible web of our national/regional/religious culture, but as we mature we choose to be members of various subcultures, based on our personalities and preferred mix of structure, organization, and meaning. We all are born and raised in a culture and then choose to become lawyers or scientists or bankers or even anthropologists. We all seek to become a member of a group or groups within which we are comfortable and feel reinforced. Most all Japanese share common cultural traits, but there are vast differences between Japanese military pilots, business executives, farmers, and fishing workers. We find our place in the modern world where we feel most comfortable, living and working with others who share our worldviews: bikers with bikers, airline pilots with other pilots, etc. When we cross these boundaries, people begin to appear to act 'strange', and we often do not correctly read the subtle clues and nonverbal communications that are constantly being sent, and miscommunications and misunderstanding easily occur.

We see this every day in our work. Archaeologists generally all share a common interest and a collaborative work approach and enjoy alternately working in the lab and digging in the field, camping out during summer field season, the thrill of discovery, and the party at the end of the day. We self-select for this professional and personal lifestyle, while within other disciplines, such as history or organic chemistry, their specific 'lifestyle' attracts different personalities who equally value aspects of their work culture, the quiet of a library while searching a collection of fragile documents, or the structure and order of the white coated chemistry lab. Each community has their own internally understood set of norms and accepted (or tolerated) behaviors, and shared concepts of roles, responsibilities, and boundaries. These cultural webs envelop us and are quite invisible to us from within our own cultural bubble, while the 'strangeness' of others is readily apparent to us.

The role of national cultural differences cannot be understated. When American archaeologists work in the field with our European colleagues, we find that we all share a common love for archaeology and our craft, but we find significant differences in not only techniques and methods, but a deep cultural divide between how we approach and conceptualize what we do and how we do it. This sets up a perfect environment for culture clash, cultural misunderstandings, and unsuccessful collaborations. We all have seen this in our careers, and each author of this volume could write their own version of this from their own national and disciplinary perspective.

Ethnocentrism, the viewing of people from other cultures as 'less' or 'strange' in their behavior is another commonly shared human trait that is of interest to anthropologists. We all see how we do things as 'normal' and when we come into contact with people who do things differently, it is human nature to see them not simply as another equally valid variation on a theme, but as 'less' or 'wrong'. We all do this without thinking, but we can learn to see it for what it is and to repress that urge to make fun or demean a colleague or student or local informant for acting completely normally from their viewpoint but inappropriately from ours. But first we have to understand the powerful and yet invisible role that culture plays in our lives. Conducting successful international, transdisciplinary collaborative work is itself truly an exercise in cultural anthropology, and it is helpful to, at a minimum, become aware of this.

Beyond the complex cultural aspects of collaboration, there are many other factors to consider. We are each in a different phase of our professional careers, and we are looking for different things in our work. Peer review publications are vital for aspiring tenure track professors, while graduate students may be seeking hands-on skills or data for their dissertations. Those near retirement may simply want to keep their hands in the game and do only what most interests them. We all have our own needs, desires, and timeframes, and it is important to try to understand these when putting together a team for a collaborative project. We are all at different points in our careers and have different professional and personal goals. Some have young families; some have elderly parents to care for. We also have different amounts of time that we can devote to a particular project. Balancing these can be difficult, but it can be done, and the first step is to honestly evaluate and consider what your limitations, goals, timeframe, and intentions are, and then share this with your colleagues. Is this a short-term, funded project for one publication and then done, or are you looking for a longer-term work project spanning several years? Some cultures see working on weekends and evenings as normal, even required, where others see this as an inappropriate intrusion. We all come from our own perspectives and they can be very different.

In long duration Historical Ecology studies, the work takes time, and one of the problems of these long projects is that people come and go and different roles and responsibilities may need to be shared or reassigned over the life of a single program. How long will your team members be able to work on the project? Often this is driven by funding, but things change, and people change jobs or simply lose interest. There is a common problem of loss of institutional memory when people leave, and digital archiving, as discussed above, is an important emerging answer to maintaining access to data and resources as things change. But it is vital that the questions of who owns and has the rights to use data, records, and field notes are clearly understood from the start.

Communication

Communication is the key to all of this. Open and respectful communication about what you are doing, what you think is important, and what you need creates a fertile and productive working environment. George Bernard Shaw is reported to have said "the single biggest problem in communication is the illusion that it has taken place", and so being clear and explicit not only in what you say but being sure that you are being understood by others from different disciplines and cultures is vital.

Teamwork

Working in teams together can be difficult and we need to be aware of our own levels of expertise and experience. Some of us are better at, and are more experienced, in working in team environments, and some project activities are more team oriented as well. Some are more personally team-oriented, while others prefer to work alone. Some Historical Ecology disciplines such as archaeology are inherently team efforts, while many others are individual researchers, and we have to learn how to work together.

Solutions

There are many things that we can do to address these complex issues, both in the practical and short term and also in the longer view.

In the short term, you might consider the following:

- Learn from the literature and know what others have done. Study other projects and their goals, methods, data, and results. Learn from the success and problems of others in terms of collaboration.
- Hold virtual meetings on a regular basis and keep good minutes online.
- Set realistic but real short-term, incremental deadlines to keep the project moving. Make progress in small steps. Focus on making progress, including acknowledging making small steps such as finding a new map, a new document, or other incremental steps.
- Have participants present their work and demonstrate their disciplinary toolkits periodically, so that the team understands who is doing what and how it fits together. Leave plenty of time for questions and discussion so that people can explore the connections between the pieces and brainstorm.
- Teach each other the basics of what each participant and their work and data can and cannot do. What do you and your data and analysis bring to the project? How does it fit with the work of others? What can you

do well and what can you not do? We tried to explicitly consider these issues in each chapter of this volume. Understanding the roles and capabilities of all the participants creates an integrated project approach, but this requires that everyone learn something about what and how the others do their work.

- Hold in-person meetings whenever possible. With Covid, we all became recluses, linked only by Zoom and similar tools, and they kept the world going, but we should not become too reliant on the ease and speed of virtual meetings. We often try to schedule meeting times at international conferences which we all attend, so that we can have that valuable face-to-face interaction. Nothing replaces face-to-face meetings and personal interaction.
- Start a journal club, where one person selects and reads an article of interest in turn and summarizes it for the group at each meeting, to keep abreast of new developments and better understand each other's literature, methods, and results. This is a very efficient way to keep up with new developments and to see what others are doing and how that might be of value to your work.
- Consider your funding situation up front. How much can you do with the funding on hand, and how likely is additional funding and on what schedule? You can do a lot with little to no funding (we have learned this lesson well), but it slows the project down. Money makes things happen quickly because people can fund their working time. The backside is that you can spend a tremendous amount of time and energy writing proposals that don't get funded.
- Track your progress using the tools presented in the previous chapter. Manage your project and know when things are moving and when they are not, where funds are being spent or not, and where things are getting bogged down. Use shared environments like Google Docs so everyone has access to all the information. Make sure that people update things.
- Set deadlines and stick to them, and do not fall into the trap of ever-receding rolling deadlines. Constantly slipping deadlines are actually no deadlines at all, and people become used to being able to put things off again and again. Develop a culture of meeting deadlines, so set realistic ones that can be met and reward your colleagues when they make progress.
- Be productive! Try to create an ethos of productivity and reward people when they produce. There is no substitute for producing.
- Ultimately, Be kind, supportive and curious towards each other's work. Academia is deeply founded on skeptical criticism. For research to be trustworthy, its liability must be tested and scrutinized, which may lead to destructive negative criticism. We must not forget that we are humans and that we need to feel safe and supported in order to be creative. Positive feedback and open curiosity will both allow for more open sharing of ideas, and also be more fun for everyone.
- Never assume what you don't really know, and never assume negative intent when a misunderstanding or miscommunication would explain the problem.

In the long term

Collaboration, like so many human things, is a learned skill, but it is rarely taught or addressed in a professional or academic context. Like teaching, it is just assumed that we learn how to do it, and people have to figure it out on their own, usually by making mistakes. This is a major structural failure of our current educational paradigms. For the longer perspective, we should all promote the issues of cultural education and practical team building in our educational activities, especially at the undergraduate and graduate school levels. Teaching our students about these issues, what they are, and how to deal with them should be an explicit part of our educational activities. Please consider incorporating these into your teaching and work environments.

We can do this through a mixture of team exercises, conflict resolution exercises, and team building activities. Each of these are important. We need to create and require structured team activities and allow students to work through problems and have them learn ways to resolve these conflicts in an academic setting where failure can be a positive learning experience and not a career-ending disaster. We can consider each 'failure' as a learning experience. In the end, we need to provide our students with the skills of how to work in diverse teams, and this is rarely explicitly offered. Also, we all know that increasing international travel and academic exchanges and field programs will help create a more capable next generation of globally minded scholars. Each student should be encouraged to study abroad, learn a foreign language, do summer field work in a foreign country, and engage in other cultural broadening activities as a part of their standard academic training.

For our more established and experienced colleagues, we all should also be honest about the hard lessons that we have learned and how we have addressed these issues, both successes and failures. Often, these are considered 'dirty laundry', not to be professionally discussed except in private, but we all have lessons and techniques that we have learned regarding international and interdisciplinary team skills that we should be more willing to share more openly to improve the state of the practice and to better prepare our students and younger colleagues for what they will face. We all want to point out our successes and naturally tend to hide our failures, but we can all learn from failure as much or more than we can learn from success. Be honest and open about sharing what did not work in the past, in order to help others avoid the same pitfalls.

Conclusions

Working together in research projects that cross cultural and disciplinary boundaries can be difficult. It can certainly complicate the work, and it also inherently slows things down, but it is a vital aspect of conducting Historical Ecology research, and it can be done. We can also take comfort in the fact that this is not a new problem. In Richard Maye's translator's introduction to Fernand Braudel's A History of Civilizations, he points out that, in the introduction to the very first issue of the seminal *Annales d'histoire économique et sociale* journal in 1929, the editors Lucien Febvre and Marc Bloch (the founders of the Annales school which has significantly influenced Historical Ecology) wrote:

> "Nothing could be better than for each person, concentrating on a legitimate specialization, laboriously cultivating his own backyard, nevertheless to force himself to follow his neighbor's work. But the walls are so high that they hide the view… It is against these deep schisms that we raise our standards" (Maye, 1993).

So let us again knock down those walls and enhance those views and raise our standards anew.
Happy gardening.

References

Baldwin, Roger G., and Deborah A. Chang 2007. "Collaborating to learn, learning to collaborate." Peer Review, vol. 9, no. 4, fall 2007, pp. 26+. Gale Academic OneFile, link.gale.com/apps/doc/A174195830/AONE?u=anon~556a5f12&sid=googleScholar&xid=81df57b9. Accessed 28 Aug. 2022.

Jones, Elizabeth A., Anna Westin, Scott Madry, Seth Murray, Jon Moen, Amanda Tickner 2017. How to Operationalize Collaborative Research. in Issues and Concepts in: Historical Ecology: The Past and future of Landscapes and Regions. Carole Crumley, Anna Westin and Tommy Lennartsso, eds. Cambridge University Press. Pp. 240-275.

Madry, Scott 2022. Culture: The Hidden Inhibitor and Enabler of Our Dreams of Space in Multicultural foundations and influences of human space exploration IAA Cosmic Study VI.17. International Academy of Astronautics, Paris, France.

MaMarzano, Mariela., D. Carss, and S. Bell 2005. Working to make interdisciplinarity work: investing in communication and interpersonal relationships. In: Journal of Agricultural Economics, Vol. 57, Issue 2, July 2006 Pages 185-197.

Maye, Richard. 1993. English translation of A History of Civilizations, by Fernand Braudel, p. xviii Penguin Books.

CHAPTER 19

FINAL CONCLUSIONS AND RECOMMENDATIONS

ANNA WESTIN, ELIZABETH JONES, SCOTT MADRY

This chapter addresses what we have covered, what we have learned, and where we might go from here. We make specific recommendations for those considering beginning an Historical Ecology project, or any similar landscape-oriented project that crosses traditional disciplinary and cultural boundaries, each of us three editors from our own individual experiences and from our work with this book.

What have we presented here?

This volume was designed to be a practical and understandable guide to the underlying techniques and methods of Historical Ecology research. Our goal was to provide a single volume that would enable and foster additional research in these related fields, and to, hopefully, allow you, the reader, to avoid some of the many mistakes that we have made along the way. In the 18 chapters above, we have tried to provide an understandable look at many, but by no means all, of the various pieces that can be included in this exciting domain of research. We recognize that there are important aspects of Historical Ecology that we did not cover, but we hope that we have included most of the basics. We sought to provide a series of coherent and understandable looks at the types of evidence, where they came from and how they work, including case studies of each disciplinary domain. We have also considered how to work with the various data sets and their analysis and integration, as well as project management, and how to collaborate and work together across disciplinary and cultural boundaries. We hope that we have, at least partly, succeeded, and have provided you with a useful toolkit for starting and successfully conducting such research projects, including finding collaborators with appropriate skills. We also intended this to be used as a textbook for courses at both undergraduate and graduate levels and in several fields of study, and we hope that this will help instructors to offer more courses in Historical Ecology and related fields and to get more students engaged in this fascinating domain of research.

What have we learned along the way?

For each of us, the three editors of this volume, our own academic journeys have been a complex mixture of success and frustration, planning and happenstance, good fortune and dead ends. We have each taken our own unique path, but we have found common purpose in working together across the great chasms of disciplinary borders, and have, we hope, advanced the state of play in the process. Ultimately, we all feel that our individual journeys have been worth the effort, and we would do it all again, if hopefully better. We have learned that it takes time to conduct long-term diachronic research, but that it is well worth the effort. One of our primary intents for this volume was to improve and make such work more efficient.

Here are some recommendations that the editors would like to make to students or colleagues who are considering conducting similar research projects. The recommendations are based on our experiences coming from different academic disciplines and experiences and we have chosen to clarify this by each presenting our individual recommendations.

Recommendations from Anna Westin - agrarian historian and ecologist

Historical ecology can challenge established "truths" in history and ecology. Ecosystems are, and have always been, the basis of our material world, economy, and inspiration as well as causes of conflict. Historical research made with no, or little, thought on the role of ecosystems, therefore risks drawing the wrong conclusions about past communities and conditions. Including deep ecological knowledge within historical analyses will add new perspectives, pose new questions, question old interpretations, and can therefore rewrite history. Similarly, ecosystems have, by tradition, been described with no or very little historical knowledge. The fact that most ecosystems have been under the influence of humans must be taken into account in order to understand how ecosystems have been shaped. Historical Ecology has a key role in conservation biology, since the management of biodiversity rich, human-influenced ecosystems must be based on knowledge about the historical processes, natural and anthropogenic, that shaped them. Historical Ecology research takes place in the intersection between history and ecology and has the potential to challenge established "truths" in both these academic fields. The following recommendations have guided my work and that of my Historical Ecology colleages, in order to come further in bringing new knowledge to both history and ecology.

Weaving multiple sources of knowledge, from the archives and the field. The different sources of knowledge can be seen as warp and weft in a woven fabric, which together generates a fuller picture than the different threads would reveal side by side. The integrated picture is created from dialectic methods weaving together information from sources (for example archival documents, cadastral maps, biological cultural heritage and interviews) where information derived from one source is used to formulate questions to use when addressing another knowledge source. The findings in the second source will typically generate new questions, used to address other sources and then the process continues until satisfaction. This also means that the sources, including the field, need to be revisited several times before the work is done. This interplay between the knowledge sources is key to understanding the complexity of past landscapes.

Take your time in the field. In all kinds of fieldwork, it is important to take the time to ponder and reflect several times on what you see. We all have our individual mental "glasses" or biases that condition us to see what we expected. In order to let the unexpected also appear before our eyes, we need to take the time and allow ourselves to look with fresh eyes and an open mind. Then we will be able to observe new details, look at things from different angles and perspectives, allowing a fuller picture for our interpretation.

Include research members with other kinds of knowledge and know your own "glasses". Interdisciplinary research relies on knowledge from different disciplines. Although it is important that each person has at least a basic understanding of the disciplines involved, we cannot be an expert on everything. We need to collaborate with persons that have other kinds of knowledge and experiences than ourselves. Even if it is possible for one person to be good in many things, having several people will always bring other knowledge and perspectives to the process. In addition to the academic background, it is important to acknowledge our own history. A person with a farming background will have a better understanding of agriculture in practice than a city-person that never set foot on a farm. Farming experience will, for example, be useful for interpretations regarding farming methods in a wide sense. Similarly, a person with craft skills will have an advantage when it comes to understanding how tools were made, or the time required to produce textiles.

Including intuition in data interpretation. The interpretation of data is not always straightforward. As mentioned in earlier chapters, it is crucial to estimate the quality of the data in the process of interpretation in order to neither over- nor underestimate their usefulness. On the other hand, my experience is that intuition is a useful tool in getting ideas for interpretations. Intuition is the subtle feeling of "knowing" without knowing how we know. We use intuition all the time in our everyday life, and it is also an important part of all research for getting new ideas and findings which may be tested against the data.

Our current rationality cannot be applied to historical conditions. The overall aim of Historical Ecology is to understand the past. Through the work with different kinds of historical data, we literally try to travel through time and see what was going on with people and ecosystems. Since data does not reveal everything, much of this understanding relies on our interpretation of that data. In the interpretation lies a "time-bias", meaning that we have difficulties imagining the important aspects that are no longer present. For example, people in pre-industrial societies traveled a lot, and most people traveled by foot. Rare sources like diaries may reveal people's daily walks to the fields, herding the livestock, the employer, markets, social visits, and church. But in general we can hardly imagine the implications of travels for people's daily lives, their social networks and what was going on when people met on paths and roads. The importance of religion, social networks, informal economies, health problems and common beliefs of human-nature relationships are difficult to imagine given that norms, values and perceptions may have been very different from ours. The solution to this is to apply an open mind, test interpretations that may be "out of the box", and to be ready to re-imagine our understanding of the past.

Ecosystems have changed through history. Our understanding of ecosystems and how they work comes from the current landscape, which sadly consists of ecosystems that are biologically eroded and very different from the historical ones. The current dense and planted forests are very different from forests in the past, which often were grazed and used for multiple purposes, and consequently were much more open. Pre-industrial agriculture depended on vast areas and a large variation of semi-natural pastures to feed the livestock. The current areas of semi-natural pastures are limited to a few percent compared to what we had around 1850. The remaining pastures do not exhibit the entire variation in soil types, nutrient content, openness, and grazing regimes that have been present in historical landscapes. Being aware that ecosystems have changed allows for a more open mind in interpreting past landscapes. Research should also adopt a holistic approach that includes as many aspects as possible of a past landscape (e.g. plant and animal communities, water distribution, soil conditions, climatic regimes and prevailing weather patterns, land-use practices, settlement patterns, etc.).

Have fun together, be curious and prestige-less. No one is an expert in everything but if we allow ourselves to ask "stupid" questions, we will break out of our boxes and create new findings.

Recommendations from Elizabeth Jones historical anthropologist/ archaeologist/ genealogist:

Spend time learning about the general context of the historical period(s) you are investigating. Read general histories of the period–social, political, technological, economic and cultural histories, as well as ecological, climatic, and geological studies. Misinterpretation is always a danger in dealing with the past, with the tendency to attribute our modern understandings of how things work and our current environmental contexts to the people inhabiting those past eras. Learning as much as you can about the practices and mindsets of historical times can help mitigate our biases in working with all kinds of historical data.

Spend time reading outside your own specialty, and read carefully and thoughtfully the contributions from other specialists on your interdisciplinary team. Many "aha" moments come from the cross-fertilization of your own ideas/interpretations with those coming from other disciplinary perspectives and data sources. Ask the other specialists on your team questions about their work so that you understand, at least at some level, how their facts and conclusions are derived. Hopefully some of this will be done with sharing in team meetings, but go beyond the more superficial sharing to ask detailed questions and have many in-depth discussions about how your own data relates to the datasets of others.

Be imaginative about possible sources of data relating to human-environment interactions. Don't just fall back on the obvious or usual sources. Explore all sorts of historical data for useful information. An example would be the 17th century French parish records on baptisms, marriages and burials. Today (and since the standardization of the 19th century) these types of vital statistic records are not very informative of people's interactions with their environments (except when looking at broad statistical trends), but in past centuries, parish priests would oftentimes add notes to the entries on weather conditions, diseases running through the community, crop failures, detailed information on occupations and farming practices, and how people were related to each other, all of which can inform about the human/environmental interface. Even in the Middle Ages, bored scribes would sometimes make comments in the margins of the manuscripts they were copying about current conditions and practices. The art, photos, literature, newspapers, advertisements, personal correspondence/diaries, tax records, etc. of historical periods can contain valuable information, either in the form of raw data, or clues to interpret the data you have.

Pick a research project/research questions that are useful to the people in the area under study. It is a tenet of Historical Ecology that learning the history of how people have interacted with their environments over the course of human history is of benefit in generating ideas and a range of tried and true models for creating a sustainable planet going forward. However, we can always choose among dozens or hundreds or even thousands of research questions to answer that fall within this scope of the broad goals of Historical Ecology. So, in choosing particular research questions, we might as well choose ones that are useful and that have meaning for the local inhabitants of the area under study. One can choose questions that have direct impacts on future land use, or that touch on cultural heritage and have historical significance to the people whose land is being studied without sacrificing any academic rigor or objectivity. To do this, local representatives should be included in the process of exploring possible research avenues, and also, the results of the project should be disseminated beyond scholarly books and journals in venues and media that are accessible to the local populace.

Include local inhabitants on your research team. Including local representatives as integral and respected members of the research team (even if they don't participate as often or as intensely as the professional researchers), not only ensures that the project remains relevant to local interests, it also will directly benefit the quality of the research. I cannot count the number of times that a conundrum in the interpretation of the data has been instantly cleared up by a local inhabitant. These residents not only have a more intimate knowledge of their environment, they also often have knowledge of land-use practices and understandings going back generations handed down from their forebears. Additionally, they may have historical documents, maps (often of their family's property), or items of material culture (like historical farm implements) that they would be willing to share with the project. The value of this Traditional Ecological Knowledge (TEK) is discussed in Chapter 10, as well as ways to effectively and respectfully engage locals in the research.

Be creative with funding and keep going. Conducting long-term diachronic research often requires substantial funding to pay for salaries, travel, equipment, special analyses, data storage and archiving, etc. Projects that have steady and secure funding for decades at a time are relatively rare. I have witnessed many projects falling apart and stopping mid-stream when a major funding source has dried up. Don't give up. There are very many ways to fund projects, from large all-encompassing grants to small piecemeal pots of money for a specific analysis or financing a trip or paying for a student researcher's time. This is where having a project that is useful to local entities can be of value as it can open up sources of public funding outside that of normal academic channels. Over the many decades that our project has been going in Burgundy we have found ways to parcel out the work so that in times of little to no funding we can work on the aspects of the project that don't require funds (e.g., working on data already collected, doing quality control, writing up results), saving things like travel and equipment purchases for when funding becomes available. The important thing is to keep the momentum going and focus on the things that can be done with the funds currently available.

Recommendations from Scott Madry, Archaeologist/GIS and remote sensing specialist/historical cartographer:

Understand the relationship between your data and your research questions. There is an important issue regarding the relationship between the questions that you want to ask and the data that you have to work with. In GIS courses, I have often used the analogy of a restaurant to this type of academic research. In this kitchen analogy, you, the Historical Ecology researcher, are the chef or cook, trained in various types of cooking skills and techniques. Some are French trained master chefs, some are hamburger stand cooks, each has a different mixture of skills and experiences. You work in a kitchen that is filled with various tools; pots, pans, knives, and blenders. These could be the GIS, ethnobotany, paleolimnology, remote sensing, documentary history interpretation, genealogy, and other data processing and analysis software and capabilities that you have: GPS receivers, GIS and remote sensing software, qualitative data analytic programs, and more. Finally, you need the food to cook, and this is our shared data, presented in detail in the various chapters of this volume. You can have a customer come in and want baked salmon with rice, but you have to have the raw food to make the recipe to serve the customer or they have to choose something else or go elsewhere for dinner. Our Principal Investigators and colleagues are the customers at the table. "I want this! Fix me that right now!" The data analyst is in exactly the position of the cook in the kitchen. You have a certain level of skills, you have some tools but not others, and you have only the data that you have. You cannot cook food you do not have, and you cannot process data you do not possess. There must be a reasonable relationship between the ultimate questions we want to answer and the data that we can access and process. We simply cannot ask certain research questions unless we have the data at the right scale and right tools to process it with. We have to carefully match the data that we have, our tools for processing that data, and the questions we want to address. Sometimes we simply cannot answer a given question with what we have, and sometimes, when new data unexpectedly becomes available, new questions can be considered and new avenues of inquiry are opened to us. Learn how to cook in the Historical Ecology kitchen.

Work backwards in time. It is important, if at all possible, to work progressively back in time, from the present back through the data increasingly remote back in time wherever possible. This is especially true in the processing of historical maps, GIS data, aerial photos, and satellite imagery. The scale and spatial accuracy of such spatial data generally get less and less detailed the farther back you go, so start at the present and then work back in a stepwise and consistent pattern backwards through time. The lens gets progressively darker the farther back you look. We did not have this luxury when we started our work in Burgundy long ago, and we went right from our current maps to our 1759 Cassini map, which was the first historical map we acquired years ago, and then worked forward as we got new data. This did not ultimately work well, as we started with the least accurate historical map (ultimately), which had the most spatial error, and much data had to be re-registered again a second time later. So, if you can, always work from the newest and best data back through time. Tasks such as georegistration and the extraction of land use and land cover data will be more accurately done in this way, producing better results. The same holds true for understanding all types of historical data.

Quality control. It is vital that you thoroughly vet all data that you acquire from other sources or develop yourself. Using students and volunteers to work with data is always an aspect of academic projects, and it is a good thing. It allows students to learn vital skills and gain useful hands-on knowledge and generates useful data. But the old adage "Garbage in, Garbage out" is true in this type of project, and so it is vital that you establish a process of Quality Assurance and Quality Control (QA/QC) for all of your data from all sources. The concept of 'error propagation' is important in all projects using GIS, and small errors in one category in one data layer can easily spread to other, derived layers, quite unseen. Our practice is to have a second set of eyes always do this QA/QC check before new data are 'cleared' to be shared and used for analysis. People should never be relied upon to have to check their own digital work, just as it is very difficult to copy edit your own writing. We often see what we know should be there, rather than what is actually present. We frequently find small errors that must be fixed before the data are made available for use, both in data we generate and also in data acquired from government agencies. This is another good reason for accurate documentation of work and metadata and paradata. You want to be able to determine, after the fact, which work was done by which person so that each dataset has a documented record. Even data created under contract by professional companies contain errors, we have found.

Establish standardized processes for working with your data. And then stick with these, or alter them when needed, but document this process. Each person should do their data documentation as they go, and keeping work notes and field journals is also important. Your data and project will often last longer than short-term student workers, so having a clear record of what was done by whom will let the next person understand what needs to be done. It also allows the project managers to work backwards and determine where and how mistakes were made. I always suggest to students (and colleagues) that they should open an MS Word or Google Doc and track, day by day, the project work they do, which files they worked on, where are they stored, what did they do, where did you put the newly created files, what did not seem right, questions that were raised, etc. I have such files dating back to the mid 1990's. One approach is to have 'Cleanup Fridays', where project participants take a part of a day per week to, rather than make progress and do new work, look back at the work of the week, review documentation, ensure that metadata are completed, backups are completed, and that all the documentation is complete so that you can begin anew the following week. Such a standard schedule ensures that, periodically, all the data are reviewed, documented, and are under control. Take the time to document what you are doing. Although it is unusual, we have worked in the Burgundy region for over 45 years now, and there is no way anyone can remember what was done when and by whom unless it is documented. Document what you do as you go.

Versioning. Specifically regarding the GIS and remote sensing data, but for all data sets, you should give consideration to how you will manage multiple users of the database, and how you provide frequent updates of your 'standard' GIS database so that everyone on the project is working with the correct and most up to date data. If you have more than one person working with your digital data, keeping all the people working with the same data version is important but difficult. As individuals make changes and create new, derived layers, these must be shared appropriately on a regular schedule, and all project participants should be aware that new or revised dataset is available and should be used. There has to be a recreating of the 'master' project dataset on a regular basis, perhaps quarterly or semi-annually or whenever important new data are made available. Ensure that multiple, periodic, offsite backups are routinely created. We rotate 3 Tb hard drives at project member's homes, offices, and even a bank safety deposit box, because stuff happens. As an aside, we jokingly refer to our working French GIS database version as "GISFinal", knowing that, at least for this project, there will never be such a thing. It is a reminder that, with our GIS data, there will never be a final version, it is constantly a work in progress. But you do need to periodically update your 'master' or working version, and make sure that, as individuals create new files or revise data, that these are documented and shared, with the appropriate metadata, after they are properly vetted so that everyone is working from the most recent and correct data. Errors propagate through a GIS, and data with errors that are used to create new data propagate these errors. Garbage in, garbage out.

Continue to search for data. Do frequent searches for new data, both at known sources and in new ones. With this in mind, you should frequently re-search the archives, libraries and web sources that may have new and relevant data. In the United States and France, for example, libraries are continually updating their digital content of maps, documents, and other files. Unlike in earlier times, you cannot look once and move on. You must re-search your relevant data repositories on a regular basis, and you will be rewarded, as more and more archives digitize their vast holdings and new content is continually being added.

Work on working together. The difficulty of different personal goals, speed of work, priorities, ways of working together, cultural differences, and different personalities all complicate each project in unique and ever-changing ways. Working together over time is just difficult on so many levels, especially across cultural, international, institutional, and disciplinary boundaries. It is just hard. You need to be open and tolerant, and air grievances in a positive and constructive manner. Communication is the most important thing. As the saying goes, 'gang up on the research problems and not on each other'. Make a commitment to learn how to work together. It is harder than it seems that it should be, but we can all do it much more successfully if we make the effort and openly address the issue.

Keep up. In an interdisciplinary endeavor like Historical Ecology, it is extremely difficult to keep up with new developments, techniques, and ideas across the various disciplines that are involved. As stated above, it is a good idea to establish some approach to this problem. For example, you could start a 'journals club', as mentioned before, where for each monthly meeting you could rotate through your group and have one team member read one new journal article and present a brief synopsis of it as it relates to your project. Not in depth, just a brief overview of the paper, methods, key results, and implications for your group. This can help keep your team up to date while sharing the work efficiently, and also having interesting interactions as a group. Try it.

Support Open Source. Try to work using Open Source tools and data. This is helpful in many practical ways, particularly as we can include people from around the world in our work without the barriers of cost, language, and commercial licenses. These seem insignificant to most of us in North America and Western Europe, particularly in the academic realm where commercial software products are generally provided without cost, but these barriers are significant to many others, including local participants, and we should make every effort to have our work be open and inclusive. Allowing students to keep the tools and data they learned to use at university when they graduate enables them to be immediately productive in their next position, and this approach also fosters collaborations internationally with partners who cannot afford the cost of commercial tools. This goes for publishing as well. Try, whenever possible, to publish in Open Source journals and publications so that you can reach the broadest audience around the world. Open Science is an important new direction, and NASA has declared 2023 to be the year of Open Science. Support Open Source.

Make Progress. Above all, make progress. Do not allow ever retreating deadlines to become the norm. We are all busy, and we all have other commitments. Be productive by first learning ***how*** to be productive. It is possible. If you can just focus for one hour each day on your project work, just one hour, you can make very real progress in what you do. Do not settle for excuses. Don't wait for funding, or permission, or for the stars to align. Just begin and make progress in small ways every day. Set short term goals and meet frequently, even if by Zoom or other remote means if you must, but also do face-to-face meetings on a regular basis when you can, and just keep moving forward. If others cannot get things done next week, carry the load.

You can be much more productive than you are, or think you can ever be, if you will just focus your efforts and do a bit of work on your project each day. Learn how to be more productive by seriously considering how you conduct your work. Stay a half an hour later at work, write just a single paragraph every day, search for missing maps or documents online one afternoon each week, spend Friday afternoons cleaning up your data, do some analysis... do ***something.*** Being productive is a learned skill, so spend some time studying and learning how, and you will be very richly rewarded. Make an effort to learn how to be productive and encourage others who you work with to do the same. We can all be more efficient, and we can all make more progress than we do. Learn how to be more productive and do not settle for all the usual excuses. Make progress.

Help to Create Historical Ecology 2.0 A good friend and colleague of mine once said "You cannot predict the future, but you can help create it", and this is true. Help to explore all of the fascinating new technologies that we have presented here, especially in chapter 16 on emerging technologies and find ways to integrate them into your research. Stretch out, reach out, and examine how these extraordinary new capabilities can enhance what we do. Be among the innovators who find new directions and help to create Historical Ecology 2.0.

Final Conclusions

You will notice that each of the three editors had quite different recommendations to present. An important part of this type of collaboration is maintaining diversity in unity. In collaborative, interdisciplinary research, areas of agreement do not have to obliterate differences of opinion or perspective. The three editors, themselves, have different professional backgrounds and nationalities. The working conditions for research for an American academic versus an American independent scholar versus a member of a Swedish research institute are very different. Funding and time constraints differ and the varying disciplinary expertise lends itself to different perspectives on the same research questions. These differences make collaboration seem difficult and laborious at times, but it is these very differences that enrich the results and create understandings that are truly greater than the sum of the parts.

The entire group of authors of this volume come from different disciplines, national cultures, and are at different points in our careers. Somehow, we have found a way to work together and have already articles together in different constellations before doing this book. Writing this book has been challenging in many ways, but we worked it out along the way. None of the authors had specific funding for this work, which slowed down the process considerably. The book did not end up exactly as we had planned. Some of the original chapters were not written, parts of their contents merged with other chapters, and some new ones appeared along the way. We planted a seed some years ago when we planned the book. We gave water and nourishment to the seedling, watched it grow, and in the end the book became exactly as it should be. Now the fruits are ready to pick. We have learned much from the work and we sincerely hope that this book will be useful for you.

Historical Ecology is a research framework that is not fixed and done. On the contrary, it is constantly developing and anyone can contribute. It is very difficult to give practical advice on starting and successfully conducting Historical Ecology projects, but we hope that we have given you some helpful ideas, useful information, practical techniques, sources of data, and most importantly, the inspiration to start your own journey. You can do this. Our best advice is just to begin where you are, work with the questions that inspires you, be curious, and search for other likeminded people who wants to explore some fascinating aspects of Historical Ecology together. We hope that this book, and our efforts that went into creating it, will be helpful to you. Good luck! And now:

Der Worte sind genug gewechselt, Laßt mich auch endlich Taten sehn!

“Enough words have been exchanged, now at last let me see some action!”

(Goethe, Faust I)

References

Goethe, J. W. V. (1837. Faust.New York, Verlags-handlung, 471 Pearl st.

ABOUT THE AUTHORS

PROF. SCOTT MADRY, EDITOR

Dr. Scott Madry is a professor emeritus of the International Space University in Strasbourg, France, for whom he taught programs all over the world for 35 years. He currently is a research associate professor of archaeology at the University of North Carolina at Chapel Hill, and is a research associate at the UNC Research Laboratories of Archaeology. He also serves as the President of Informatics International, Inc., a global geomatics consultancy. He was elected a member of the International Academy of Astronautics in 2022. He is a chercheur associé du Laboratoire Archéologie et Territoires de l'UMR 7324 CITERES, Université François-Rabelais/CNRS, Tours, France. Dr. Madry lectures all over the world on the applications of space technology for GIS, remote sensing and their applications, including its many uses for cultural and natural resource management and disaster response and recovery. He is a long-term proponent of Open Source software, and has presented over 180 short courses around the world on the use of Free and Open Source geomatics tools such as QGIS. He has conducted archaeological and anthropological field research in Burgundy France for over 45 years, including being a Fulbright scholar at the Université de Bourgogne in Dijon, being a visiting scholar at the Centre archéologique européen at Bibracte, and as a visiting professor at the Unversité François Rabelais in Tours. He is a researcher, teacher, and well-published author in the field of space applications and geomatics, having published ten books, multiple book chapters, over 75 papers and articles, and 14 technical reports. His books include: *The Handbook of Satellite Applications* (1st and 2nd editions); *The Handbook of Small Satellites*; *Space Systems for Disaster Warning Response and Recovery*; *Global Navigation Satellite Systems and Their*

Applications (1st and 2nd editions); *Innovative Design, Manufacturing, and Testing of Small Satellites*, and *Disruptive Space Technologies and Innovations: The Next Chapter*, all published by Springer Press. He has been a three-time Fulbright Scholar; at the Université de Bourgogne in Dijon, France, the University of the Witwatersrand in Johannesburg, South Africa, and at the University of Cape Town, South Africa. He was twice awarded the President's Volunteer Service Award for his humanitarian work with the American Red Cross and the URISA GISCorps. His university website is http://scottmadry.web.unc.edu and you can contact him at: madrys 'at' email 'dot' unc 'dot' edu.

ASS. PROF. ANNA WESTIN, EDITOR

Anna Westin has a PhD and is Associate Professor in agrarian history at the Swedish University of Agricultural sciences, SLU. My current position is as researcher at the Swedish Biodiversity Centre at SLU. With a master in biology the focus of research is in the interface between agrarian history and ecology, integrating academic and local expert knowledge. My main interest is human-nature relations from a historical perspective, specifically regarding the use of local ecosystems such as hay meadows, pastures and arable land. Detailed knowledge of how historical land use has shaped past and current landscape is needed to manage biodiversity and biological cultural heritage of today. A substantial part of my research is therefore made in interaction with national authorities with responsibility for various aspects of landscape management. In practice, I combine historical sources with ecological field work, and the geographical focus is in South-central Sweden.

DR. ELIZABETH ANNE JONES, EDITOR

Elizabeth Jones is an adjunct assistant professor of anthropology and research associate of the Research Laboratories of Archaeology at the University of North Carolina at Chapel Hill. She received her Ph.D. from UNC in 2008 and she has conducted research in North Carolina and France. Her research interests include the Historical Anthropology of European Medieval through Post-medieval periods and 17th-19th century America; Methods of Ethnohistory, Historical Demography, Historical Ecology and GIS landscape studies, Archaeology (ceramics)and Material Culture studies (clothing); research especially related to historic farms and land use, as well as farm families and gender constructions.

ALINA-SORINA BIRO

Alina-Sorina Biro is currently a PhD candidate at the Institute of Botany, Slovak Academy of Sciences, Bratislava, Slovakia. Her scientific coordinator is PhD. Monika Janisová and together with her team they study the bio-cultural heritage of the semi-natural grasslands in the Carpathian Mts. using advanced vegetation sampling methods, soil and biomass analysis, but also by investigating the traditional ecological knowledge of the local communities in the selected sites of the study.

She has previously worked between 2016-2021 as scientific coordinator and social media responsible for The Alexandru Borza Botanical Garden in Cluj-Napoca, Romania.

DR. EVA GUSTAVSSON

Dr. Eva Gustavsson is Assistant Professor at the Department of (heritage) Conservation at the University of Gothenburg, Sweden. She is head of the bachelor programme in Gardening and Landscape Crafts and teaches mainly in subjects relating to landscape history, biology and biological cultural heritage. Her research at the Craft Laboratory, which is a national center for craft science and craft professionals, concerns historical landscape management regimes, and its traditional craftsmanship (e.g. traditional ecological knowledge), for the conservation of biological cultural heritage.

Before entering into academia, she worked at the Lake Vänern Museum for Natural and Cultural Heritage, as a museum biologist, where she produced exhibitions, developed education on environmental issues and worked on projects concerning sustainable tourism in the Lake Vänern Kinnekulle Biosphere Reserve. During this employment she also underwent her PhD-education at the Department of Ecology, Swedish University of Agricultural Sciences.

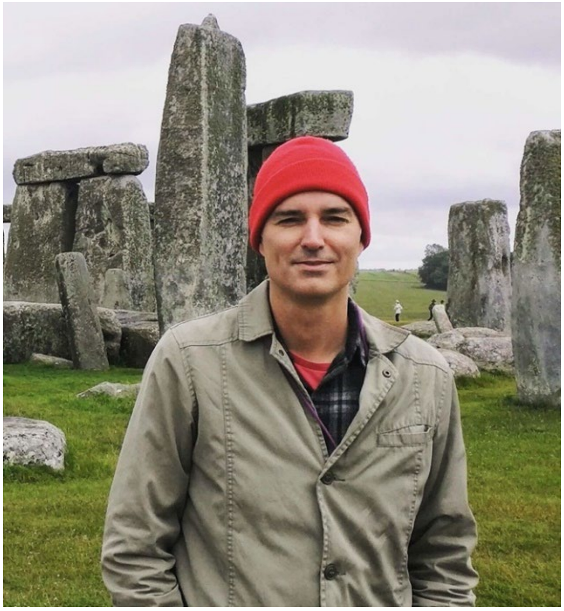
DR. ANAMARIA IUGA

Dr. Anamaria Iuga is the head of the Ethnology Studies department at the National Museum of the Romanian Peasant, Bucharest, Romania. Her research interest includes the dynamic of material culture and intangible heritage (such as storytelling, dynamic of contemporary rituals, oral cultures in the digital era, traditional ecological knowledge). Her PhD thesis was on the topic of the dynamic of traditional objects and rituals that occur in the festive space of the peasant house in northern Romania, Maramureș. Since 2009 she carried out interdisciplinary research on environmental anthropology in Romania, especially on the traditional ecological knowledge used for the traditional management of grasslands (hay meadows and pastures). Since 2017 she is a chief editor of MARTOR Journal (www.martor.muzeultaranuluiroman.ro), the anthropological journal of the National Museum of the Romanian Peasant, and in 2016 she coordinated, together with Bogdan Iancu, the special issue on the flexibility and continuity in hay meadows management.

DR. COSMIN MARIUS IVAȘCU

Dr. Cosmin Marius Ivașcu is Assistant Professor at the Department of Biology-Chemistry, Faculty of Chemistry, Biology, Geography at the West University of Timișoara. His main teaching disciplines are Nature Conservation at the bachelor degree and Biological Anthropology and Human Ecology at the master degree. Since 2011, he has been engaged in the study of traditional ecological knowledge, biodiversity rich cultural landscapes and ethnobiology mostly in Romania. He has also been visiting researcher at the Department of Landscape and Vegetation Ecology of Kassel University from Germany in 2019. Main research interests are related to the role of traditional ecological knowledge in managing species rich semi-natural ecosystems, cultural landscapes and historical agro-silvo-pastoral practices, historical ecology, biocultural heritage, pastoralism, ethnobiology (both ethnozoology and ethnobotany) and the cultural perception of the environment.

GREGORY JANSEN



Greg is a research software architect specializing in digital repositories and computational treatments for digital archives. He is part of the professional faculty at the School of Information Studies at the University of Maryland at College Park. He has led diverse projects for the U.S. National Parks Service, the University of North Carolina at Chapel Hill, and the Institute for Museum and Library Services. His research interests include high scale digital platforms, computer vision, machine learning, and digital preservation. Greg has an undergraduate degree in cultural anthropology, reads in related subjects, and relished this opportunity to engage with the study of historical landscapes and people.

ASS. PROF. PER LAGERÅS

Prof. Per Lagerås has a PhD in Quaternary geology at Lund University and is Associate Professor in agrarian history at the Swedish University of Agricultural Sciences. He holds a position as palaeoecologist at The Archaeologists, National Historical Museums, Sweden, where he is doing pollen and macrofossil analysis within rescue-archaeology projects. Among his publications are the books The ecology of expansion and abandonment – medieval and post-medieval land-use and settlement dynamics in a landscape perspective (Riksantikvarieämbetet, 2007), Environment, society and the Black Death – an interdisciplinary approach to the late-medieval crisis in Sweden (Oxbow Books, 2016), and Archaeobotanical studies of past plant cultivation in northern Europe (Barkhuis, 2020, co-edited with Santeri Vanhanen).

Contact info:

The Archaeologists, National Historical Museums, Odlarevägen 5, SE-226 60 Lund, Sweden, phone +46-10-480 82 51, e-mail per.lageras'at' arkeologerna 'dot' com

PROF. PAUL LANE

Prof. Paul Lane is the Jennifer Ward Oppenheimer Professor of the Deep History and Archaeology of Africa at the University of Cambridge. He specialises in the landscape historical ecology and archaeology of eastern Africa over the last c. 5000 years, with emphasis on the transitions to food production, landscape domestication, the trade in elephant ivory, settlement dynamics, maritime heritage, and the archaeology of enslavement and emancipation. His research focuses on demonstrating the applied relevance of knowledge about the past to meeting contemporary needs with special emphasis on capacity building and knowledge co-production with local communities.

ASS. PROF. TOMMY LENNARTSSON

Dr. Tommy Lennartsson is Associate professor in conservation Biology at the Swedish Biodiversity Centre, belonging to the Swedish University of Agricultural Sciences in Uppsala. Starting as a plant population biologist, the research soon broadened to biodiversity in landscapes that are shaped or influenced by human land-use, both current land-use such as transport infrastructure, and historical historical use of landscapes, e.g., by farmers and reindeer herdsmen. Lennartsson is particularly interested in how specific historical land-use activities have shaped biotopes and provided habitats for species of plants and animals, and how the knowledge about such relationships can be used to design governance of nature and biodiversity today. And, conversely, how knowledge about such relationships can be used to trace human history in the landscape by interpreting habitats and species as a biological cultural heritage. Lennartsson's research has mainly been conducted in agricultural, forest, mire, alpine, semi-arid and coastal landscapes. Most of the research is interdisciplinary and performed in close collaboration with historians, ethnologists and anthropologists. The research includes practical management experiments, and Lennartsson works part-time at a County conservation organisation, Upplandsstiftelsen.

DR. NILS STANIK

Dr. Nils Stanik is currently a Postdoc at the Department of Landscape and Vegetation Ecology, University of Kassel, Germany. After he studied Landscape Architecture, Landscape Planning and Landscape Ecology at the University of Kassel, he focused early on applied topics of conservation-related ecology in cultural landscapes. His research interests focus on the connection between the vegetation and human-implied shaping forces at different scales (landscape, habitat and species scale). His current research includes semi-natural mountain grasslands and heathlands in Central Europe with respect to past landscape and land-use change and future climate change. His work is based on experiments, field surveys as well as spatial analysis to investigate cause and effect relationships between elements of landscapes as holistic entities and their implication on ecosystem services.

DR. HÅKAN TUNÓN

Dr. Håkan Tunón is director of the Swedish Biodiversity Centre, Swedish University of Agricultural Scences, Uppsala, Sweden. He has a background as natural product chemist, pharmacognocist, and ethnopharmacologist, but has for the passed thirty years been working more broadly with ethnobiology, traditional ecological knowledge, and indigenous peoples and local communities. Much of his activities have departed from the UN Convention on Biological Diversity and Swedish implementation of article 8(j) and 10(c), i.e. traditional knowledge and customary use of biological diversity, in close collaboration with the Swedish Saami Parliament and other organizations related to indigenous peoples and local communities. He has also together with knowledge holders been involved in the Swedish-Norwegian nomination of Scandinavian pastoralism, e.g. summer farming, as a representative cultural heritage within the UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage. Dr. Tunón has authored and edited numerous scientific papers and books related to ethnobiology and rural history, mostly in Swedish.

APPENDIX 1

GLOSSARY OF TERMS AND LIST OF ACRONYMS

A

Active remote sensing- remote sensing sensors that emit their own electromagnetic radiation towards the target, which is then reflected back to the target and analyzed. Systems such as RADAR and LiDAR are active systems. As opposed to passive RS systems.

Aerial photography- Aerial mapping photographs used to create maps and land use/land cover information.

Agrarian history- The historical study of agriculture and the role of agriculture in human history and activities.

AI- Artificial Intelligence. Computer technologies that can mimic human intelligence to do useful work.

Anthropogenic- Originating in actions by humans.

Anthropology-the study of humans and human culture. Often subdivided into cultural anthropology, archaeology, linguistics, and physical anthropology

Archaeology- the study of human culture through the analysis of human remains and artifacts

Archives- Permanent repositories for documents and other items. As a discipline, the practice of preserving and providing access to data, both digital and physical.

Atlas- a combination of maps and textual data about a specific location or the entire globe. Atlases often include statistical, environmental, economic, and political data about a region, state, or nation.

Atlas.ti- A software package that is used for recording and analyzing ethnographic interviews.

B

Biocultural heritage-The biological features of culture, but also with a wider meaning to denote entire knowledge systems where indigenous people or local communities are seen as inseparable from nature, being in an intimate ongoing relationship with nature through e.g. land use, rituals and beliefs

Biodiversity- Short for biological diversity, the combination of all living things and their interactions with their own and other species and the world.

Biodiversity conservation- Biodiversity conservation is the protection and management of biodiversity in order to derive sustainable benefits for both the present and future .

Biocultural diversity- Refers to the diversity of life in all its complex forms from a human cultural perspective. It focuses on the intersection between the biological and human cultural spheres.

Biodiversity conservation- processes or projects which seek to restore past, more beneficial conditions for biodiversity.

Biological cultural heritage (BCH)- ecosystems, habitats and species which have originated from, or been shaped or favored by human utilization of the landscape and whose long-term persistence and development is dependent on, or favored by continued management. Human traces left in nature, intentionally or unintentionally. Traces on the landscape of past human-modified ecological systems. BCH consists of living organisms as carriers of historical information.

Biotopes- Individual habitats for both flora and fauna.

Bocage- a term used for regions, primarily in Europe, consisting of fields and meadows enclosed by hedges and hedgerows, often including raised banks, ditches, and other aspects of the landscape.

C

Cadastre- a record of properties, land ownership, and, often, tax information of a property by property or house by house basis. They often indicate detailed land use and land cover.

Cadastral map- a detailed map that often is made in association with a cadastre, indicating detailed land use and land cover.

Carte de l'Académie- The Cassini maps of France, the first, national set of maps using triangulation and a common set of map representations. It was a massive improvement over existing national maps. Produced by four generations of the Cassini family at the Paris observatory over 60 years.

Cartography- the art and science of the study of maps and map making.

Chain of evidence- The documentation of continuity of a document or other artifact to ensure that it is unaltered and authentic.

Citizen science- The conducting of scientific data collection and analysis by citizens and untrained individuals. Can include field work and data collection, and in the processing of data by multiple private computers and over the internet.

Coppicing- The repeated shoot harvest, similar to pollarding, but close to the ground . Also called low forestry. Repeated coppicing creates elevated stools with multiple trunks visible long after coppicing ceases.

Coordinate Reference System (CRS)- A map projection that mathematically defines the relationship between features on a flat map and what distortions were introduced relating to the true locations on the Earth's surface. All maps have a map projection or CRS.

Copernicus- a civil remote sensing satellite program operated by the European Space Agency, operating the Sentinel remote sensing satellite series with freely available data.

Cultural heritage- the physical manifestations of human culture in the past, in a wider sense, denoting our entire cultural heritage, including art, literature and intangible heritage such as traditions, perceptions and place names.

Cultural heritage conservation- This refers to issues relating to and actions taken to explore, preserve, and promote cultural heritage in all its complex aspects
.

D

Diary- A journal kept by an individual, often containing personal, local, family, and economic information. Not a document generally meant to be read by others.

DEM- Digital Elevation Model. A digital data layer, usually a raster layer, representing a topographic surface. Commonly used in GIS.

Dendrochronology- the science of dating environmental conditions, archaeological features, and more by the process of using databases derived from patterns of annual growth rings in trees and timbers.

Digital archiving- The series of managed activities necessary to ensure continued access to digital materials for as long as necessary. Also known as digital preservation.

Digital image processing- the process of manipulating two dimensional numerical arrays of data, such as data acquired by satellites or aerial sensors, using computers to extract and enhance the information contained within.

Documentation- A key component in interpretation and contextualization. A thorough documentation of observations, questions, theories, sources used, as well as how the information in those have strengthened, weakened or developed new ideas.

Document Image Analysis and Recognition (DIAR)- An evolving field that uses multispectral digital scanning, digital image analysis, AI, deep learning, and feature recognition to decipher and reconstruct damaged or faded historical documents.

Digital image processing- the analysis of digital data, including analysis of airborne and satellite imagery

Digitizing- converting data from an analog to digital format

Durable storage- This is a storage device or service that is more reliable and stable than ordinary consumer storage devices. Durable storage will include some guarantee and demonstrated past performance of file fixity and availability throughout a period of service.

E

Economic history- The sub field of history which deals with economics, financial, and business issues.

Ecology- Ecology is a sub-branch of the science of biology. It deals with the complex relationships between organisms and between organisms and their environment at all scales

Ecosystem- An ecosystem is a complex, interacting system of living organisms and their environment that interact at many scales and over time.

Ego documents- Documents written by common people, including dairies, letters, and private agreements.

ESRI- The Environmental Systems Research Institute of Redlands, California, USA, the commercial GIS firm that produces the ArcGIS family of GIS tools. The most commonly used commercial GIS.

Essential conditions- Those that must be present for a species to establish and reproduce in a given area.

Ethnobotany- The study of the complex relationship between human communities and the plant world found in their landscape.

Ethnocentrism- The human trait of seeing people from other cultures through our own cultural viewpoint and perspective, often seeing others who are different as less or strange.

Ethnographic interview-

Ethnography- Ethnography is the subfield of anthropology which deals with the scientific study and description of individual cultures around the world. It is characterized by studying cultures from the point of view of the culture itself and not the perspective of the anthropologist. It is a type of social science research that focuses on documenting and understanding cultural activities from the perspective of the people themselves.

Ethnology- A subfield of anthropology that studies the similarities and differences between human cultures.

External Analysis- External analysis is designed to determine the authenticity and the context of a document.

F

Field survey- in person surveying of an area by foot, often using GPS, data collection systems, cameras, and other recording systems to acquire detailed information on the ground.

Fixity- Fixity is the property of a digital object remaining fixed or having a fixed, immutable character. In technical terms the fixed quality in digital objects is an unaltered byte stream, which can be demonstrated over time through comparison of a newly calculated file digest with a digest calculated earlier.

Folklore- Folklore are the shared traditions, transmitted orally across generations, that are shared by a community of people or culture. Folklore can consist of tales, legends, poetry, myths, legends, and other commonly shared oral traditions.

FOSS- Free and Open Source Software, including many types of tools, including GIS.

G

Gazetteer- A geographical dictionary, used with atlases and maps. Often a collection of place names.

Genealogy- The study of family lineages, descendants, and ancestors.

Genealogy software- Computer software that is used to create family trees and family relationships.

Geographic Information System (GIS)- A computer system that stores and manipulates digital data. A combination of spatial and tabular data.

Geomatics- a synonym of GIS. See GIS.

Georeferencing (also georegistration)- the process of warping a map, image, or other spatial data in order to have it accurately lay over your other data in a GIS environment.

GNSS Global Navigation Satellite Systems- also called PNT, constellations of satellites that provide positioning, timing, and navigation services worldwide.

GPS- the U.S. Global Positioning System. A satellite-based system that provides positioning, navigation, and timing services world-wide. It was the original such system, originating in the 1970's and has now been joined by several other national systems.

GRASS GIS- The Geographic Resources Analysis Support System, the original Open Source GIS software, originally developed by the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (USA COE CERL) https://grass.osgeo.org

Grazing pressure- the environmental pressure or impacts on a field caused by different types of field usage. For example, in pastures with high grazing pressure, nearly all vegetation is being consumed, so species that depend on yearly flowering and maturing are disfavored.

H

Hay meadow- a field set aside for the production of hay to feed animals over the winter.

Hedge- A field border consisting of living vegetation used to define fields and contain large animals.

Hedgerow- A hedge that also includes trees

Hermeneutics- The study of the meaning of words. In historical criticism, it assumes that words have stable meanings at a particular point in time.

HGIS- Historical Geographic Information System- a GIS dedicated to historical questions and data.

Historical Cartography- The use of old maps in research. The analysis and extraction of information from older maps.

Historical Ecology- Read the book.

History- The study of past events, particularly focusing on people and societies.

I

IFOV- the Instantaneous Field of View of a sensor, also referred to as the spatial resolution of an image.

IGN- The Institut national de l'information géographique et forestière (National Institute of Geographic and Forest Information) of France, the national agency founded in 1940, which produces and maintains geographics information of France. (https://www.ign.fr).

Informant (ethnographic)- A person who undergoes an interview or series of interviews with an ethnographer. This may include completing surveys, recorded interviews, etc.

Information Science- The scientific study of the storage, access, and retrieval of digital information.

Intangible cultural heritage- Aspects of our cultural heritage such as place name or other ephemeral aspects.

Interspecific competition- The competition between different species within an ecosystem.

Internal analysis.- Used to to determine the credibility of the information contained within a document used in historical analysis

J

K

L

Landsat- a satellite remote sensing system operated by the U.S., providing free, moderate resolution satellite imagery since 1972.

Landscape- All of the visible elements of a local environment, including both the natural and human-created aspects of the environment.

Landscape archaeology- The subfield of archaeology dealing with the landscape and regional scale, as opposed to individual archaeological sites.

Library science- The academic discipline of the study of libraries and library collections. Often now called Information and Library science.

LiDAR- Light Detection and Ranging- a remote sensing technique that uses pulses of optical light energy to accurately map detailed aspects of terrain and vegetation.

LOC- the U.S. Library of Congress

Local history- The sub field of history which deals with a small, local area and its inhabitants from a very localized perspective.

M

Material culture- the physical objects that are the product of human societies. All things created and modified by humans for their use can be considered to be material culture, and these are all the subject of analysis by anthropologists and other researchers.

Mentality history- The sub field of history which deals with how people at any given time thought about, interacted with, and conceived their relationships with their local environment.

Metadata- data about data, often containing information about the source, processing, location, and other information useful to better understand the information contained.

Museum- An organization dedicated to the preservation and analysis of material culture.

N

Non-documentary sources- Information collected not in documentary formats, including GPS field data, imagery, photographs, etc.

NSDA- the National Digital Stewardship Alliance.

O

Open Science- scientific work conducted using Open Source data, tools and processes. It also includes Open publishing and related topics.

Open Source- software where the original source code is available, and that can be redistributed and modified.

OpenStreetMap- An online wiki where people map their own local areas online and share the data. A global Open Source world map which is freely available. *https://www.openstreetmap.org/)

Oral history- The collection and analysis of historical information collected through interviews with people giving their personal views about their lives and environments.

Original order-This refers to the organizing scheme, including folder structures, labels, and naming conventions, within which digital objects were originally produced and used. Wherever possible the original order of materials is maintained or preserved in practice of digital archiving.

P

Paleoecology-The study of the ecology of past times and environments, the scientific study of environmental conditions and ecological relationships in the past.

Paleoethnobotany- the study of plant use, diets and lifeways of past human communities from certain areas, ecosystems and historical eras

Pannage- The right or privilege of feeding pigs or other animals in a forest. This was carefully regulated due to the potential damage to the forest.

Parish- The most local Catholic church level of organization, used throughout Europe and now adopted by several nations as the most local civil governmental structure.

Passive remote sensing- sensing systems that use reflected solar radiation to conduct their analysis. As oppsed to active RS systems.

Pasture- a field set aside for the use and feeding of farm animals and not for agricultural production.

Paradata- Data about processes, and the processes used to analyze data. Used to track how data were manipulated. See Metadata.

Pb210 dating- This dating technique uses alpha spectrometry to measure the decay of excess 210Pb lead activity, which has a half-life of 22.3 years, to determine the rate of sediment accumulation. About 5 g of dried sample, from various depths of the sediment core, is required. It is used for dating of samples too recent to use C14 dating.

Percentage pollen diagrams- The traditional method of representing species changes over time in pollen analysis.

Photogrammetry- the mathematical analysis of objects through the use of photographs. Generally used in aerial photography for mapping purpose where detailed and spatially accurate topographic maps, for example, can be created from vertical aerial photos.

Pixel- A contraction of ‘picture element’, in computers, it is the tiny individual area of illumination of a screen or display device that creates an image. In remote sensing, it is the individual areas that make up an image.

Place names- Toponymy- the study of the historical meaning of place names on the landscape, of villages and other features on the landscape.

Pollarding- The repeated cutting of tree branches at some height above ground, generally to keep new growth out of the reach of forest animals. Repeated pollarding often creates peculiar shapes of trees, such as wide and low trunk with a multitude of branches from about the same place

Pollen productivity estimates- Models of how much pollen different species produce, used in paleoecological modeling and dating.

Political history- The sub field of history dealing with politics and the impact of political activities upon the larger historical record.

PNT- Positioning, Navigation, and Timing Satellite systems like the U.S. GPS and others that provide global position and timing services. Also called Global Navigation Satellite Systems (GNSS).

Probate inventory- A legal recording of all items owned by a person a the time of their death. Generally created for tax purposes.

Projection (map)- a set of mathematical transformations used to accurately represent the curved surface on the globe to a flat map. There are hundreds of map projections, and each has its benefits and limitations for a given purpose.

Provenance- the preservation of the original context of an item, including its origin, chain of custody, and ownership.

Q

QGIS- An Open Source GIS system (https://qgis.org).

Qualitative data- Data which are not quantitative or numerical, representing opinions, values, ideas, and other information that cannot be quantitatively measured and analyzed.

Quantitative data- data representing numerical information, statistical data, and other data that present results that can be measured and analyzed.

R

R- an Open Source statistical toolset, available in Windows, Mac, and Linux. Commonly used for spatial analysis.

RADAR- Radio detection and ranging- an active remote sensing method in the microwave portion of the electromagnetic spectrum.

Raster- A digital data structure where data are represented as a two-dimensional array of numbers, often referred to as pixels. Scanned maps and satellite imagery are composed of raster data.

Reference landscape- A landscape that typifies a type of environment, often one that is now rarely seen. These are preferably studied by combining field observations, interviews, and historical sources, in collaboration with national experts.

Remote sensing- the gathering of information using sensors not in contact with the target. Often digital sensors which are mounted on airborne or satellite platforms. Used to create land use and land cover maps, terrain maps, and other environmental information.

Replica- a copy of a digital object. Replication is the process of distributing or updating copies of data.
Rubber Sheeting- a type of georeferencing, where different portions of a map or image are warped and stretched in different amounts in different portions of the image.

Ruderal- A plant that is associated with human dwellings or agriculture, or one that colonizes waste ground. Ruderals are often weeds which have high demands for nutrients and/or are intolerant of competition.

S

Scale (map)- the representative fraction of a map or digital map dataset. Scale is often represented as a fraction such as 1:50,000, where 1 unit of measurement on the map represents 50,000 on the ground. Large scale maps are very detailed, things are larger on the map, where small scale maps have a larger representative fraction and usually have less detail.

Sentinel- An Earth remote sensing satellite series, operated under the larger Copernicus program by the European Space Agency, providing freely available data.

Spectral reflectance- The unique manner in which objects on the Earth reflect light in different ways based on their specific characteristics. This allows us to identify land use and land cover using remote sensing sensors.

Spectral signature- The unique identifying characteristics of features on the landscape that can be identified using remote sensing systems.

Social history- The sub field of history which focuses on social structures and interactions rather than political or economic events.

Social-ecological System (SES)- A framework that helps focus on how ecosystems and socio-economic factors interact in detail in historical or current societies.

Source criticism- a critical examination of the used sources and an assessment of the credibility of statements made in any source of information.

Source pluralism- cthe combination of different sources in order to achieve a more complete and valid result than from using one single source.

Statistical science- the science of collecting, exploring, and utilizing large amounts of data to understand underlying trends and patterns.

SPOT- The French Satellite pour l'Observation de la Terre civil remote sensing series of satellites.

Stocking density- the number of livestock per unit of land.

Supervised classification- the process of identifying specific land use and land cover areas on the ground and telling the image processing software to locate areas of similar spectral reflectance in order to classify remote sensing imagery into thematic classes such as land use and land cover.

T

Technical debt- Digital enterprises use the concept of technical debt to refer to the software investments they must sustain in order to keep the entire project technically viable.

Temporal comparisons- The analysis of data from different dates Comparisons over time.

Thematic classification- in digital image processing of satellite imagery, the process of classifying imagery into thematic classes such as land use and land cover.

Topography- The lay of the land, the changing nature of the landscape in terms of elevation, slope, and other features.

Topographic map- a special type of map that is designed to accurately represent the topography of the area, including land use and land cover.

Toponymy- The scientific study of place names from a historical, etymological (linguistic) and geographical perspective.

Triangulation- In geometry, the process of finding a specific location by forming triangles from known points. This is the technique used for creating maps, where known points on the landscape are measured in, and other locations are tied to them using trigonometry.

Traditional Ecological Knowledge (TEK)- Practical, experience-based knowledge about plants, animals and other parts of nature. The knowledge concerns the use, management, and customs of a local region. This knowledge is transferred between generations and constantly changing.

U

Unsupervised classification- the process of allowing a computer program to classify remote sensing imagery into thematic classes such as land use and land cover.

V

Vector- a digital data format where information are presented as points, lines, and polygons, often used in GIS systems to represent features such as individual locations (points), rivers (lines), or soil maps (polygons).

W

X

Y

Z

Zebra- A type of wild horse, found in Africa (just to have something in Z).

INDEX

A

B

C

D

E

F

G

H

I

K

L

M

N

O

P

Q

R

S

T

U

V

W

Z

Historical Ecology is a dynamic and exciting field of academic research and practical knowledge. This extensive book, years in the making, is designed to provide a practical and useful guide to how this work can be done, including individual chapters on many of the different disciplines and techniques that come together to make a transdisciplinary whole. From archaeology to ecology to history to advanced computer applications like Geographic Information Systems and satellite imagery, the authors weave a web of theory, method, and technique that demonstrates the benefits, and also the difficulties, of this approach to regional analysis. This book is designed to assist new scholars to enter the field and further the skills of those already involved, and will serve as an excellent textbook or general reading for anyone interested in the intersection of human societies and their environments over time.

SLU

ISBN 978-91-88083-45-6

9 789188 083456 >