BIO-CULTURAL REFUGIA - SAFEGUARDING DIVERSITY OF PRACTICES FOR FOOD SECURITY AND BIODIVERSITY

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ABSTRACT

Food security for a growing world population is high on the list of grand sustainability challenges, as is reducing the pace of biodiversity loss in landscapes of food production. Here we shed new insights on areas that harbor place specific social memories related to food security and stewardship of biodiversity. We call them *Bio-cultural refugia*. Our goals are to illuminate how bio-cultural refugia store, revive and transmit memory of agricultural biodiversity and ecosystem services, and how such social memories are carried forward between people and across cohorts. We discuss the functions of such refugia for addressing the twin goals of food security and biodiversity conservation in landscapes of food production. The methodological approach is first of its kind in combining the discourses on food security, social memory and biodiversity management. We find that the rich biodiversity of many regionally distinct cultural landscapes has been maintained through a mosaic of management practices that have co-evolved in relation to local environmental fluctuations, and that such practices are carried forward by both biophysical and social features in bio-cultural refugia including; genotypes, artifacts, written accounts, as well as embodied rituals, art, oral traditions and self-organized systems of rules. Combined these structure a diverse portfolio of practices that result in genetic reservoirs — source areas — for the wide array of species, which in interplay produce vital ecosystem services, needed for future food security related to environmental uncertainties, volatile financial markets and large scale conflicts. In Europe, processes related to the large-scale industrialization of agriculture threaten such bio-cultural refugia. The paper highlights that the dual goals to reduce pressures from modern agriculture on biodiversity, while maintaining food security, entails more extensive collaboration with farmers oriented toward ecologically sound practices.

1. Introduction

In ecology, refugia are places where relict (formerly more widespread or abundant) species have found shelter during periods of stress, such as from forest fires or inclement climate. The term refers to areas where former conditions are maintained within broader geographical regions. In recent years the genetic material of a vast number of plants and other organisms has been collected and stored; one example is the large collection facility at Svalbard on the Norwegian island of Spitzbergen. Such collections are in response to concern of that industrial practices in landscapes of food-feed-fiber-fuel production could dangerously reduce genetic diversity, affecting nearly half of all terrestrial species (Ferrier et al., 2004; Chappell and LaValle, 2009; Phalan et al., 2011). In this way a sort of collective biological memory has been created, with the capacity to restore cultivated species and habitats.

However, if the task is to safeguard global food security[1], it is not only the biological components of ecosystems that must be curated. Due to the varying historical and geographical conditions under which species have been (and are currently) cultivated, it is also important to safeguard knowledge of management practices that relate to these conditions. Using an interdisciplinary frame of analysis, we discuss areas where food continues to be produced in a context that links biological diversity and social memory, and which carries place specific insights and experiences of stewardship (Nabhan, 2008). We call them *bio-cultural refugia*, meaning places that not only shelter species, but also carry knowledge and experiences about *practical management* of biodiversity and ecosystem services. What is the role of bio-cultural refugia when dealing with the issues of food security and biodiversity loss in agricultural landscapes and regions? This paper is not about a "museum collection" that would conserve the past; instead, it provides an intellectual perspective that can help safeguard a reservoir of practices that have been tested in a great variety of conditions and which can serve as living laboratories for innovations in landscapes of food production (Baleé, 2006; Crumley, 2007; Costanza, 2007; Dearing, 2008; Thurston, 2009; Guttman-Bond, 2010; Libby and Steffen, 2007; Paavola and Fraser, 2011). We argue here that this perspective has value in calling attention to the practical importance of diverse agricultural contexts and management practices.

As at Svalbard but in a broader context, we examine how our stock of relevant knowledge and experience should be treated. This challenge can be compared to the contemporary effort to provide a complete map of the human genome. Surely the future capacity of humankind to safeguard its food requirements is of equal strategic importance. Of course, the two projects differ in a number of ways: while mapping the human genome is essentially a natural science activity, the effort to map and safeguard agricultural practice is inter- and trans-disciplinary, combining the natural and social sciences, technology, innovation, health and practical

[1] Food security is defined as being when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996).

knowledge so that both general principles and practical insights can be derived and will be open to future modification and adaptation.

Since the agricultural revolution began around 10,000 years ago, small-holding farmers have experimented with the management of plants and animals important for their livelihood. Their solutions were "system-wide": they thought about how vulnerability to shifting conditions could be reduced by maximizing useful connections between components of the broader landscape (e.g., fields, pastures, forests and woods, water resources, soils and external human settlements). In this sense, they practiced the central concept of permaculture (e.g., Graham 1992, 2004), a focus on relationships created among elements. We will discuss these place-specific insights for the future in the same way.

The goals of this paper are to illuminate how and where collective social memory of how to steward agricultural biodiversity and ecosystem services can be carried forward between people and across cohorts. We discuss the functions of such *bio-cultural refugia* for addressing the twin goals of food security and biodiversity conservation in landscapes of food production. Our methodological approach forges a conceptual framework that draws on four major research communities. 1) Studies in social or collective memory explore knowledge constructed through shared experience and transmitted across generations (Halbwachs 1952; Connerton, 1989). The study of social memory has its basis in sociology, anthropology, literary criticism, and psychology; its methods are thus ethnography (e.g., the open-ended interview), the study of material culture (e.g., memorials, museums), documentary evidence, and experimental settings in which individual and collective memory is examined. We are particularly interested in social memory as it pertains to the transmission of place-based environmental information. 2) Food security focuses on the production, distribution, availability and accessibility of food (Ingram et al., 2010). In recent years, food security has been recognized as vulnerable to climate change, loss of ecosystem services, conflict, long supply chains and other factors to which many of the systems that produce and distribute food are prone. Many methods, both qualitative and quantitative, are used to collect information that would allow assessment of vulnerability and offer ways to reduce risk. Our paper focuses on vulnerabilities that result from the loss of biodiversity, the reduction in the diversity of agricultural practice, and the loss of practical, place-based knowledge that ensures the durability of landscapes of agricultural production.

Here we are aided by the scholarship about 3) resilience, used here as the capacity of social-ecological systems to absorb shocks, utilize them, reorganize and continue to develop without losing fundamental functions (Holling, 1973; Gunderson and Holling 2002; Carpenter and Folke, 2006). This is all framed by insights about human-environmental relations that play out at wider temporal scales than are normally considered by agro-ecologists; this perspective is provided by 4) historical ecology, a holistic, practical perspective for the study of linked human activity and environmental change on time scales from decades to millennia. Historical ecology employs concepts, methods, and evidence taken from the biological and geophysical sciences, the social sciences, and the humanities. This fourth viewpoint provides critical conceptual tools to 'cross-check over disciplinary boundaries,' reveal new patterns of association, and raise new questions (Balee, 2006; Crumley 1994, 2007; Meyer and Crumley 2011). Our approach is thus interdisciplinary; the joining of these particular research fields appears to be the first of its kind. We searched for peer-reviewed journal papers relating these concepts, and found no previous studies using the approach of this paper. We used the search functions of Scopus-document search for journal publications until 2012, and the search fields (for abstract, key words and title), of each of the terms; *food security* OR *food production* OR *agriculture* AND *social memory* AND *biodiversity*. We found only one publication, which dealt with urban community gardens. Since our previous research experience has been in Europe, this paper focuses on the European situation, but it holds insights for other regions with a long history of agriculture (Sahu, 2011).

1.2 Collective memories and practical stewardship of diversity

Insights have emerged in recent decades that highlight the role of site-specific experiences and cultural knowledge, and their storage and transmission, for stewardship of ecosystems (Altieri et al., 1987; Dahlberg, 1993; Nazarea, 1998; Jarvis and Hodgin, 1999; Almekinders and Elings, 2001; Berkes et al., 2003; Maffi and Woodley, 2010; Barthel et al., 2010; Siebert, 2011). We cannot know exactly when and how memories of past environmental changes survive, or how experiences of responses to crises from the deep past have survived. However, research has demonstrated that social memory is maintained in communities, settlements, practice and professional groups, and religions (Halbwachs, 1925/1952, Connerton, 1989; Climo and Catell, 2002; Misztal, 2003). The study of social memory is a focus of research in several fields (e.g., anthropology, archaeology, history, psychology, sociology, natural resource management), linking processes of remembering and forgetting to modes of retention and loss within their historical, cultural, and political contexts. The literature tells us that, while only individuals can be said to remember *sensu stricto*, individual memory processes derive from social interaction and are facilitated by supra-individual means, i.e., sharing with others: stories, artifacts, symbols, rituals, landscapes and the like. The work is especially interesting as regards the role of crisis, which can render memories indelible or, in certain contexts, entirely suppress them (Gunn 1994; Crumley, 2000; McIntosh et al., 2000; Nazarea, 1998, 2006; Barthel et al., 2012).

We use the term *stewardship memory* (cf. Barthel et al., 2010; cf. Nazarea, 1998), because we are discussing memories that guide people in practical—on the ground—management of species, habitats and other features of ecosystems, particularly in agro-ecosystems. This use of the term can be seen as a sub-category of *social memory,* where living species, soils and landscapes, in combination with the social carriers, are part of a 'shared container' that captures, carries, revives and transmits practical knowledge and experience of how to steward agro-ecosystems (ibid.). It plays an important role in resilience, because in times of change, stewardship memory helps renew and reorganize the capacity of social-ecological systems to generate ecosystem services, like food and pollination (cf. Berkes and Folke, 2002; cf. Folke et al., 2003). Bio-cultural refugia are places that harbor such stewardship memories.

Practical engagement in farming communities over time may result in a shared history (Wenger, 1998; McKenna et al., 2008) of communally managed artifacts and tools used in everyday situations, as well as soil technologies, species, and landscape features (Thurston, 2009). These latter tend to outlive the repertoires of practices that first shaped them, and function together as carriers of resilience in agro-ecosystems, in combination with embodied practices and knowledge (see table 1). For instance, long-term transmission of *in situ* knowledge related to stewardship of anthropogenic soils in Europe, and knowledge related to how people have responded to abrupt climate changes, has been recorded in archeology (Crumley, 1994; Thurston, 2009). Another example in traditional agriculture is the widely known practice of saving seeds selected from the harvest for the next planting (Steinberg, 2001), so that over the millennia locally adapted varieties of crops co-evolved with changing local environmental conditions and with values held by profitable farmers (Fraser and Rimas, 2010). Stewardship memories of fluctuating local environmental conditions and societal adaptations to them are carried forward through time by soils and locally adapted crops, by landraces, as well as by embodied ceremonies and rituals, oral traditions, written material, and by self-organized systems of rules (Connerton, 1989; Nazarea, 1989; Barthel et al., 2010). Such memory carriers (table 1.) are constantly shaped by social participation as well as by environmental dynamics, and they incorporate many small, almost imperceptible variations in constantly changing contexts (Wenger, 1998; Scott, 1998). Stewardship memory related to landscapes of food-fiber-fuel production reflects response to a changing physical environment, to economic fluctuations linked to it, and to histories of conflict (cf. McIntosh et al., 2000; cf. Barthel et al., 2010).

[INSERT TABLE ONE ABOUT HERE]

Table 1. The features of stewardship memory. Different carriers, or repositories, of biota as well as of human experiences: knowledge and practices (Modified after Barthel et al., 2010; 2013).

Stewardship memory extends beyond the mere extraction and collection of environmental information to a deeply integrated connection between observation and meaning among groups of people (Lawrence, 2009). In both traditional and contemporary societies, the ceremonies and rituals that carry ecological practices forward represent features of such memory (Lansing, 1991; Hanna et al., 1996; Alcorn and Toledo, 1998; Berkes and Folke, 1998; Berkes et al., 2003). Stewardship memories are always place-specific and continue to evolve, though the places that harbor such memories—bio-cultural refugia—are shrinking (figure 1).

[INSERT FIGURE ONE ABOUT HERE]

Figure 1. The figure is a heuristic model of social forgetting related to diversity of *in situ* stewardship memories in landscapes of food-fiber-fuel production. The grey bars symbolize pressures on social memories, and the red dots symbolize when such are erased and forgotten.

Perhaps the most pervasive eraser of social memory is the passage of time (Figure 4), but events like the black death, genocides—and in modern history, the green revolution—are examples of events that erode memory and results in a generational amnesia. Hence, useful memories must be packaged for transmission to the future. Transmission, both formal and informal, has been achieved in many ways. Stories, songs, and poems are passed from one generation to the next; visual and mnemonic cues are left in landscapes, monuments, and objects; the embodiment of everyday practice is taught through dance or the cadence of work; every written record is a "message in a bottle" from the past. Conversely, social memory is erased in many ways, sometimes intentionally, as, for example, by suppression of a target population's language, religion, music, or livelihood, or simply by people's moving from the country to the city. Despite these and many other threats to memory, there is considerable evidence that the collective memory of particular events can survive for thousands of years (Barber and Barber, 2004; Broadbent, 2010; Cruikshank, 2005).

In the following paragraphs we attempt to discuss some future challenges when addressing the challenge of feeding a growing human population on Earth while halting the rate of biodiversity loss in landscapes of food-fiber-fuel production, and how the perspective from social memory can be of use. Then we discuss the spatial and temporal functions of food security and biodiversity conservation that bio-cultural refugia hold. We conclude with some ideas for promoting sustainable food solutions while combating loss of diversity in the bio-cultural refugia that produce vital ecosystem services needed for long-term food security.

2. Alarming rate of biodiversity loss while feeding a growing human population

Agriculture associated with industrialization has been driven by the need to enhance efficiency gains, the result of demographic changes, urbanization and the global economy (Steffen et al., 2007; McMichael 2009; IAASTD, 2009). Practices are applied uniformly over broad spatial scales, are dependent on intensive use of artificial fertilizer, pesticides, herbicides, etc., are narrowly specialized on certain crops, are dependent on non-renewable resources, and are increasingly open to the use of genetically modified organisms[2] (Horlings and Marsden, 2011). Spatial disconnection of consumers from places where food is produced and increasing but uneven patterns of consumption seem to accompany this direction of agricultural development. The forces driving change require a reorganization of the content and direction

[2] The use of GMOs is at the heart of an ongoing strategic debate in the EU, to which we refer. However, this paper does not take part in this debate.

of the knowledge production system[3] to fit the challenges, although the skewed distribution of financial capacity increasingly erodes a fair competition between knowledge production systems in food production (Norgaard, 2010).

2.1 Food production and Food security

Industrialization of agriculture has led to a remarkable increase in food production, which, along with advances in medicine, has enhanced life expectancy and health for growing populations in most nations (Rosling, 2007). Despite this, the number of undernourished children in many countries constantly increases, and history records people's starving even when food supplies in their own nations were at overflow levels (FAO, 2006, 2008; IAASTD, 2009). Focusing solely on food production is not enough: food security on the regional scale, with spatial access to cultivation areas that are rich in ecosystem services, is equally important for feeding the world sustainably (Watts and Bohle, 1993; Sen, 1994; Daily et al., 1998; Ingram et al., 2008; Ericksen, 2008; Perfecto and Vandermeer, 2010; Fraser and Rimas, 2010; McMichael, 2011). Additional efficiency gains may meet demographic pressures, raising economic capacities and changing eating habits. It is nonetheless likely that pressure from the global food market will continue, a development that intensifies practices destructive to diversity such as chemically intensive monocultures[4].

Using monocultures to increase efficiency is worrisome from a sustainability perspective since there is a clear trade-off between short term efficiency and long term resilience (e.g.; Folke et al., 1996; Holling, 1996; Holling and Meffe, 1996; Ehrlich, 2002; Fraser, 2003; Carpenter and Folke, 2006). While management of agricultural landscapes that host diverse crops and habitats are more costly in terms of labor, such places may prevent loss of ecosystem services in soils, waters and terrestrial landscapes that are needed for long-term resilience when disturbance is projected to be frequent and varied. On the other hand, industrial monocultures

[3] The concept of a knowledge production system has arisen mostly in research and innovation policy circles and the academic fields reflecting on these phenomena. A current example is the ongoing work in the European Union, especially in its Directorate General for research and innovation, around the needs for reform of the agricultural knowledge production system, addressed especially by the standing committee for agricultural research (SCAR).

[4] Monocultures are used here in a spatial sense, as one crop variety planted over vast areas. In this definition the choice of crop for a particular area may change in time, into another (spatial) monoculture. The temporal dimension of monoculture (same crop planted year after year on the same area) may have bearing for pest-crop science, but also for agro-ecologists studying biodiversity. The spatial and temporal dimensions of diversity are of equal interest.

save labor costs, but demand expensive investment in technology and non-renewable resources, which in turn structure future success or failure. In such a polarized picture both directions are needed to feed a planet of nine billion. Industrialized monocultures have received much criticism of late, partly due to the core belief in technological innovation *(cf.* Strumsky et al., 2010). In some parts of the world the industrial model has resulted in what has been termed an efficiency trap (Scheffer and Westley, 2007): returns are high at first, but with time energy costs escalate and marginal returns from fertilizers and pesticides diminish, while environmental problems—such as green house gas emissions, water degradation, topsoil loss, and biodiversity loss—accumulate. These and other side effects of the current industrial model suggest that alternative and innovative green ways of farming must be considered (Netting, 1993; IAASTD, 2009; Cordell et al., 2009; U.N., 2010; Horlings and Marsden, 2011; Fraser and Rimas, 2010; Lin et al., 2011). It is in this context that policy-dialogues that incorporate bio-cultural refugia may be of interest.

2.2 Loss of diversity and ecosystem services

While bio-cultural refugia protect vulnerable species, the rate of biodiversity loss due to agricultural practices associated with chemically intensive monocultures is extraordinary (Vitousek et al., 1997; Tscharntke et al., 2005; Rockström et al., 2009; Phalan et al., 2011). An estimated 43% of all remaining terrestrial species are connected to landscapes that are presently or have recently been used to produce food-feed-fiber-fuel (Ferrier et al., 2004; Chappell and LaValle, 2009). Many of those species are now threatened by the imposition of efficiency-driven contemporary agriculture and the accompanying loss of long-established sustainable practices. Globally, and at an alarming rate, "holistic" solutions related to practical stewardship of species and habitats are quickly discarded (Figure 1), in a kind of ongoing generational amnesia (Leopold, 1949; Kahn, 2002; Emanuelsson, 2010). Entire habitats and wild species associated with them, as well as landraces—local varieties of domesticated animals or plants adapted to their natural and cultural environment—have been lost or are on extinction trajectories (Benton et al., 2003; Negri, 2005; Emanuelsson, 2010). Unfortunately, it is now well established that the current loss of biodiversity in agro-ecosystems also erodes fundamental ecosystem services that underlie the resilience of production, such as soil fertility, pollination and natural pest control (Kearns et al., 1998; Gurr et al., 2003; Tscharntke et al., 2005; Steffan-Dewenter et al., 2005; Foley et al., 2005; Biesmeijer et al., 2006; Klein et al., 2007; Ingram et al., 2008).

2.3 Two opposing strategies for the wicked problem: Land-sparing vs. land-sharing

Ecologists agree that efforts to increase food production rapidly may lead to catastrophic rates of biodiversity loss if sustainability strategies are not implemented (Rockström et al., 2009; Phalan et al., 2011; Perfecto and Vandermeer, 2010). Strategies to address biodiversity loss while feeding nine billion people differ (Green et al., 2005): some scholars argue for meeting the challenges through land-sharing, the spatial integration of food production and conservation of biodiversity; spatial-modelers and agro-economists informed by ecology assert that a strategy of land-sparing is needed, in which biodiversity conservation is separated spatially from food production. The latter strategy assumes that space for biodiversity should be separated from human activities and should be conserved elsewhere, while higher yields per land unit are produced on areas of prime soils (Avery, 2007; Balmford et al., 2005; Emsley, 2001; Green et al., 2005; Godfray, 2011; Phalan et al., 2011). Hence, the land-sparing strategy can easily be misused to defend intensive use of non-renewable agrochemicals on heartlands with the argument that larger areas of 'pristine' ecosystems then will be saved in order to halt current rates of biodiversity loss (Godfray, 2011). For biodiversity conservation alone, related to a given global food production, there seems to be no clear support for either strategy, but solutions must be specific to each particular landscape and situation (Green et al., 2005; Hodgson et al., 2010; Benton et al., 2011). The land-sparing strategy may be rational in some parts of the world, but it makes little sense in landscapes with a deep history of agriculture, since some ecosystem service providers needed for high yields, including many species of solitary bees and insectivorous birds, are culturally adapted to a great number of agricultural practices (Green et al., 2005). The ubiquitous industrialization of agriculture leads to the disappearance of such practices, in a process of social forgetting, along with the disappearance of species: hence, our emphasis on social memory.

In Europe, the main drivers of such interlinked loss of bio-cultural diversity in landscapes of food production are 1) chemical-intensive monoculture in agricultural heartlands (Tscharntke et al., 2005; Chappell and LaValle, 2009) and 2) the simultaneous abandonment of marginal lands, which leads to the extinction of many species that have adapted to the traditional agricultural practices now collectively forgotten on a grand scale (Crumley, 2000; Lindborg and Ericksson, 2004; Ericksson et al., 2002; Emanuelsson, 2010). Species and genotypes in the cultural landscapes of Europe are (to various degrees) emergent properties of the millennia-long co-evolution of humans and other species in the production of food-feed-fiber-fuel (Rindos, 1980, 1984, 1986; Groonenborn, 2009). Past conditions and practices have been culturally transmitted across cohorts, and such have interacted with local organisms and habitats, shaping ecosystems in landscapes of food production and extending cultivation into marginal areas (Rindos, 1980; Crumley, 1994; Nabhan, 1997; Barthel et al., 2005; Kaplan et al., 2009; Emanuelsson, 2010).

4. Bio-cultural refugia: sources of resilience in landscapes of food production

Industrialization commenced in the 1800s and accelerated after the end of World War II; before that, the back-breaking labor of smallholders resulted in landscapes that were often relatively rich in habitats, species and genotypes (Benton et al., 2003; Eriksson et al., 2002; Lindborg and Eriksson, 2004; Negri, 2005; Fraser and Rimas, 2010). Traditional agricultural strategies tended to maintain the soil's nutrient content (Thurston, 2009), so that a variety of vegetation covers grew in different stages of succession. Dynamic mosaic landscapes provided terrestrial and aquatic habitats for a vast array of species across the aggregate spatial scale (Bengtsson et al., 2003, 2005; Emanuelsson, 2010). The time depth represented by this capturing and storing of experience and the development of such strategies in Europe and elsewhere is measured in millennia (figure 2 and figure 4).

4.1 Diversity as an agricultural strategy

Historic agricultural landscapes,[5] reservoirs of thousands of years of experience, persist in remote, marginal, and mountainous areas and are re-emerging in parts of Eastern Europe (Netting, 1993; Beaufoy et al., 1994; Jarvis and Hodgkin, 1999; Negri, 2003; Eyzaguirre and Linares, 2004; Emanuelsson, 2010; Dahlström et al., 2013). These are the place-specific and unique bio-cultural refugia, where biodiversity in agro-ecosystems emerged and continues to evolve.

[5] Also called low intensity farming systems. These involve a minimal use of fertilizers, agrochemicals, and other external inputs; in this and other respects they can be distinguished from the intensive forms of agriculture now dominating the more fertile regions of Europe (Beaufoy et al., 1994). Such areas are also called agro-forestry systems, poly-cultures or intercropping farming systems (Horlings and Marsden, 2011), or traditional farming systems (Emanuelsson, 2010).

Around eight thousand years ago, plants and animals that had been domesticated in various regions of Southwest Asia—Turkey, Iran, Iraq, and the eastern Mediterranean—began to spread to Europe along two major routes (Kaplan et al., 2009; Gronnenborn, 2009). One followed the Danube River west from its delta in the Black Sea into the heart of temperate Europe: France, Germany, and Scandinavia. The other followed the Mediterranean littoral west into North Africa, Greece, Italy, southern France, and Spain (Gronenborn, 2009) (see figure 2).

[INSERT FIGURE TWO ABOUT HERE]

Figure 2. Historic routes of domesticates into Europe from the Fertile Crescent.

By about 4000 BCE farming societies were established throughout Europe (Gronenborn, 2009). The heartiest of domesticated species adapted over millennia to the new local habitats, under the selective pressure of both increasingly proficient farmers and dramatic shifts of climate regimes over the European continent (see figure 3). Diversity in agriculture in Europe has evolved in the course of coping with erratic and sometimes abrupt environmental fluctuations, and accumulated experience and responses to such changes has been captured (see figure 4), in living biota, technologies such as ponds, terraces and gardens, and in customs (Gunn, 1994; Nazarea, 1998; Crumley, 2000). It is in bio-cultural refugia where distinctly *regional* biota, agricultural technologies and customs are preserved and revived.

[INSERT FIGURE THREE ABOUT HERE]

Figure 3. Shifting climate Regimes over the European continent during the period 1200 BCE-800 CE. The picture illustrate how prevailing weather systems dramatically have 'wandered' across the continent, which may have been experienced as disturbing to social-ecological systems (Modified from Crumley, 1993).

[INSERT FIGURE FOUR ABOUT HERE]

Figure 4. Climate change forces adaptation of food production systems. Experience of climate variability is maintained in stewardship memory and can survive for thousands of years, but social memory can also erode with time and disturbances (Compare with figure 3).

Using diversity as strategy has been a way for farmers of earlier eras to build resilience. It is hence an 'old truism' that resilience scholars teach us: diverse and overlapping functions, in combination with spatial variation within and between people and their ecosystems, provide a buffer for living with surprise (Gunderson and Holling, 2002; Low et al., 2003, Folke et al., 2003). Response diversity is a useful concept in the resilience discourse (Elmqvist et al., 2003). A place where one ecosystem service (e.g. pollination) is maintained by a diversity of different species is more resilient, because each species often responds differently to a given disturbance: such disturbances function as selective pressures and are encoded in the DNA of populations (Folke et al., 1996). One of many pollinating species (e.g., the domesticated bee) may be eradicated by a climate related disturbance, but other pollinating species may be able to persist and compete for the vacant niche if they have evolved different responses to such a disturbance. A variety of species in a system provides a variety of possible responses to disturbance, and increases the resilience of the particular ecosystem service. The same logic, can be applied in agro-ecosystems by way of practical management; this strategy, which has a long history, is now re-emerging with new labels (Graham 2004). Bio-cultural refugia are areas where diversity—*as strategy*—still is imprinted on the physical landscapes.

4.2 Bio-cultural Refugia and the value of spatial diversity

From the perspective of geologic time, refugia function as genetic reservoirs during both slow and abrupt climatic changes by providing habitats for survival of populations (Haffer, 1982; Tallis, 1991; Tribsch and Schönwetter, 2003). Similar processes of "ecological memory" play out on shorter time scales as well in the spatial dynamics of biota (Nyström and Folke, 2001; Bengtsson et al., 2003). In the context of dramatic ecological disturbance—fire ravages a landscape or the land use changes to a monoculture—ecological memory (Bengtsson et al., 2003) depends on three factors: the diversity of mobile species that provide critical ecological material (seeds, eggs, pollen) to a disturbed area; the diversity and quantity of surviving organisms in the disturbed area (large trees that survive fire, seeds that remain in the soil and take advantage of the disturbance); and the physical morphology of the landscape, including migration routes and diversity of refugia from which novel ecological material can be vectored into the disturbed area (Lundberg and Moberg, 2003, Bodin and Norberg, 2007; Bodin and Saura, 2010). Such ecological perspectives help us understand spatial sources of resilience, but not the dominant features that uphold such sources in culturally shaped landscapes. In vast regions of industrial monocultures, bio-cultural refugia are source areas for farm biodiversity: these are the mosaic landscapes where species have evolved slowly under the selective pressure of human labor. Management practices and species (as encoded in their DNA) preserved in bio-cultural refugia have been tested "by the tooth of time." They are products of coping with ecosystem states and a climate that changed over time, from wet to dry to wet again, from warm to cold to warm again (see figures 3 and 4). Some bio-cultural refugia preserve experiences of farming on marginal lands: making terraces in sloping terrain, conserving moisture in arid regions, or managing poor soils. The ecosystem services needed for long term food security are provided in a complex bio-cultural context; understanding the biological conditions alone is simply not sufficient.

4.3 The food security function of Bio-cultural refugia: small holders and gardens

Bio-cultural refugia are often made up of smallholder systems. Instead of land owned and managed by only a few, bio-cultural refugia provide access for a broader proportion of citizens both to agricultural land and to social networks that provide *in-situ* experiences. Spatial proximity has historically been a powerful determinant for food security, especially when transportation has been costly, or when supply lines have been disrupted (Barthel and Isendahl 2013). For instance, people living in cities with little access to locally grown food have been vulnerable to periods of food shortage, as occurred in Europe during the two World Wars. 800,000 German city-dwellers starved to death during the "hunger years" of 1917-18. Smallholders and food gardens during those periods provided relief, but only insofar as the skills and knowledge needed for effective food production could be transmitted over time and across social groups (Barthel et al., 2013). In Britain during the first World War, the number of local food gardens surged from 600,000 to 1,500,000, and they played a crucial part in supplying city people with vegetables. Parks and sports fields were tilled; even the ground near the Queen Victoria monument at Buckingham Palace was plowed up to grow vegetables as part of the "Every Man a Gardener Campaign". By 1918 urban smallholders alone had provided 2,000,000 tons of vegetables to the hungry people in cities whose lines of supply had been severed. The number of such gardens declined after the war, only to explode again during World War II (Ibid.).

People in rural areas also suffer food vulnerability when they lack access to agricultural land. For instance, the 'successful' implementation of industrial practices in developing countries during the green revolution of the 60s and 70s, led to loss of biodiversity, as local farmers and the *in situ* knowledge that they preserved were overwhelmed by agribusiness conglomerates. Expensive fertilizers, pesticides and high-tech irrigation systems bankrupted middle class farmers and poisoned entire land- and seascapes. Even if yields rose on a national level, due to unequal purchasing power, more people starved as they lost access to their own farmland (Thurston, 2009). In most areas where smallholder systems prevailed, food security of the populace remained intact (Netting, 1993). Smallholders are cultivators practicing intensive permanent diversified agriculture on relatively small farms in areas of dense population (Netting, 1993). They may be landowners or proprietors with stable, private, long-term—often heritable—tenure rights which coexist with common property arrangements for such resources as pastures, forests and waterways (Ostrom, 1990; Hanna et al., 1996). Smallholders provide food security when spatial distance becomes a barrier to food availability because of energy scarcity, volatile financial markets or war, as in Cuba or Eastern Europe after the collapse of the Soviet Union (Altieri et al., 1999; Round et al., 2010; Wright et al., 2009). The various effects of the fall of the Iron Curtain in Europe in 1989 offer interesting examples of the enduring importance of trans-generational transmission of *practical management* by bio-cultural refugia. With the collapse of the USSR, Cubans—already under embargo—were starving. The average per capita calorie intake fell from 2,900 a day in 1989 to 1,800 calories in 1995. Citizens drew on still-extant knowledge of agricultural practice to develop an urban farm system (*organopónicos*), which now ensures a stable food supply (Premat 2009). In the decade that followed the fall of the USSR and the Ceaușescu government, before reforms led to a solid recovery, Romanians experienced continuous economic hardship. One of the most successful strategies for workers during the transition was to return to family holdings in the countryside. This was possible because Romanian agriculture was never collectivized, and because of the survival of social institutions that kept family ties strong and enabled the transmission of place-based agricultural knowledge to new farmers (Wästfelt et al. 2012).

Smallholders maintain stewardship memories of how to farm the diverse set of species needed for ecosystem services and how to be self-sufficient in food production. This puts the out-migration of people from rural land in Europe in a new light. When farmers and gardeners leave rural landscapes, their experience and knowledge of how to farm in distinctly different contexts goes with them, a kind of social forgetting. Analysis of the reasons underlying this erosion of social memory is useful, to be sure (McMichael, 2009, 2011; Norgaard, 2010;

Harvey, 2010), but countering the trend also requires incentives for people to stay in rural areas and to enable a larger proportion of citizens to engage in farming (Netting, 1993; Sen, 1994; IAASTD, 2009; Pretty et al., 2006; Frison et al., 2006; U.N., 2010; Horlings and Marsden, 2011).

Industrialists—adherents of both capitalism and communism—have considered smallholders to be technologically primitive and economically backward (Emsley, 2001; Avery, 2007). Current industrial agriculture often produces higher yields in proportion to labor costs and emphasizes practices that minimize such costs. Smallholder systems require higher labor costs in proportion to yields, but are less dependent on non-renewable resources and often—but not always—implement more climate-smart practices (Netting, 1993; Lin et al., 2011). Of even greater importance from a food security perspective is the now emerging evidence that productivity per unit of land is inversely related to farm size, and that smallholders using agro-ecological practices may substantially increase world food production in total, and food security regionally, with substantially less erosion of biodiversity (Rosset, 1999; Pretty et al., 2006; Perfecto and Vandermeer, 2010; Evans, 2009; IAASTD, 2009; U.N., 2010; Fraser and Rimas, 2010; Horlings and Marsden, 2011). The small size of these farms and the larger number of people working on them make it possible to monitor fields more often and maintain gardens, ponds and orchards, resulting in a sustainable agriculture with little or none of the erosion and degradation that frequently accompany large scale farming (Netting, 1993; Berkes and Folke, 1998; IAASTD, 2009).

Even if ‘big’ is not always ‘bad’, we see opportunities to engage in policy dialogues when renewing the European food strategy by taking into account the linkages between smallholder systems and bio-cultural refugia, especially when searching for solutions regarding biodiversity loss and of how to revive shrinking rural areas by increasing job opportunities, as, for instance, in serving emerging markets for organic food and locally-grown food (DeLind, 2002; Friel et al., 2007; Petrini, 2007; Pelletier et al., 2008; Steel, 2010; Fraser and Rimas, 2010; McMichael, 2011). An agricultural policy that balances current support to industrial monocultures with greater financial support for smallholder farms using agro-ecological principles could encourage a wide variety of rural ways of life. Such a policy has a greater chance to build resilience related to food security for the long term by supporting smallholders who are not entirely reliant on non-renewable resources, and by re-organizing diverse agro-ecosystems that better fit distinctly regionally contexts, in which ecosystem services are generated in landscapes of food production (Netting, 1993; Sen, 1994; Daily et al. 1998; Ingram et al., 2008; Fraser and Rimas, 2010; De Schutter and Vanloqueren, 2011).

A simplified agricultural landscape that has lost its diversity and refugia is vulnerable to disturbances like fires, pest outbreaks, rainfall fluctuations or climate change, and may as a consequence shift into a new and less resilient type of landscape with subsequent loss of ecosystem services (Foley et al., 2005; Enfors and Gordon, 2008; Gordon et al., 2008). It is in this context that bio-cultural refugia become relevant to food security and biodiversity management, as well as to the sustenance of vital ecosystem services underlying the long-term success of farming (as called for by Godfray, 2011). On the aggregate spatial-temporal scale, such bio-cultural refugia increase the range of potential responses to external stressors like climate change, emergent diseases, rapidly developing markets, energy shortages, and volatile financial systems. Like the resilience function of the human immune system, which reflects historical exposure to pathogens, memories of earlier agricultural practices accumulate and reflect experience. Bio-cultural refugia carry a wide array of experiences from deep time history (figure 4), and provide human shaped genetic reservoirs—source areas—for vital species connected to traditional agricultural landscapes. Food security requires management practices that carry experiences and knowledge for how to farm the diverse set of species of bio-cultural refugia. These cultures of habitats (Nabhan, 1998) for food production serve as banks of real-world farming experience that can be mobilized, revived and recombined to meet rising needs: hence, bio-cultural refugia.

In summary we have shown here that our approach offers scholars and practitioners a way to re-examine taken-for-granted assumptions, such as the position that biodiversity conservation and food security cannot, *or should not*, be addressed in the same locales. Taken together, the independently derived research traditions used here offer a pragmatic framework that captures the synergy between human activity and the biogeophysical world, and that can generate diverse solutions to issues of food security and biodiversity management at scales from local to global. It can also help develop baselines for decisions about how to steward landscapes of food production that are more politically and historically informed, by recognizing that all learning from history takes place in the context of contemporary values (Halbwachs, 1925/1952; Ernstson and Sörlin, 2009). With a sustainable future as our goal, we argue that a shift in practice from "older" to more "modern" might not necessarily be a linear progression. Earlier, now "historical" practices, when seen with fresh eyes in a contemporary setting, are often reintroduced (Berkes et al., 2000). Such returns to old solutions re-link to various forms of tacit knowledge (Polyani, 1966; Sensiper, 1998), especially with regard to management practices in agriculture and food processing (Crumley, 2000; Nazarea, 2006; Barthel et al., 2010). Understanding such tacit knowledge and practices, and how they are carried in social memory, requires recognition of the deep practical experience and the explicit and implicit values and concerns engrained in various (agri-) cultures (Scott, 1998; Agrawal, 2002).

4. Conclusion

The Convention on Biological Diversity set targets for 2020: pressures from modern agriculture on biodiversity are one key area that must be addressed (Perrings et al., 2010). At the same time, there is a need to maintain food security for a growing world population. These goals cannot be achieved in isolation (Godfray, 2011). We have addressed the need to meet these dual goals simultaneously by introducing a novel concept: *bio-cultural refugia*, the containers of agricultural biodiversity and which carry experiences of environmental variation extending into deep time.

The methodological approach behind the perspective is the first of its kind in combining the discourses on food security, social memory, historical ecology and resilience thinking, and it argues that the rich biodiversity of many regionally distinct cultural landscapes has been maintained through a mosaic of management practices developed in relation to local environmental fluctuations and carried in collective social memories spanning millennia. We show here that the social memory of how to steward agricultural biodiversity and ecosystem services is carried forward between people and across cohorts, both by biophysical elements including species, landscape features, written accounts and artifacts. These material and immaterial forms function as mnemonic devices that structure management practices. Many arts and practices such as ceremonies, songs, stories, and institutions function as memory carriers. Combined, they constitute a diverse portfolio of practices for how to deal with environmental variation, and it is in bio-cultural refugia where such portfolios are found. Because they are not recognized as important, the Common Agricultural Policy threatens bio-cultural refugia in Europe (Mikulcak et al., 2013). An ongoing and accelerating generational amnesia of traditional practices and experiences in agricultural landscapes accelerates the erosion of biodiversity and regulating ecosystem services.

The rate of biodiversity loss due to agricultural practices associated with chemically intensive monocultures is alarming and threatens to erode the capacity of entire landscapes to produce regulating ecosystem services. Simplified landscapes of food production are increasingly subject to climate change, related disturbances, and other shocks of globalized society that challenge food security. Bio-cultural refugia protect vulnerable species and simultaneously produces food, and it is here that smallholders are still important. They can counteract such vulnerabilities and play an essential role in building resilience in landscapes of food production, along with reserves, national parks and other protected habitats in relation to ecosystem services and biodiversity (Colding and Folke, 2001, Bengtsson et al., 2003, Tengö et al., 2007).

This contribution highlights the value of drawing on the rich fund of experience of biodiversity and ecosystem functioning that is embedded in human societies, traditions and cultures, and the importance of nurturing hard-won ecological knowledge and understanding in social-ecological systems (Berkes and Folke, 1998). This is particularly true for a broad spectrum of issues related to the challenges of the Anthropocene era (Steffen et al., 2007; 2011; von Heland and Sörlin 2012). A key policy-message from this paper is the importance of safeguarding interlinked bio-cultural diversity, a key facet of future stewardship strategies for our Planet.

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