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KNOWLEDGE PRODUCTION AND LEARNING FOR SUSTAINABLE FOREST LANDSCAPES: THE EUROPEAN CONTINENT'S WEST AND EAST AS A LABORATORY*

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To support human well-being, green (or ecological) infrastructure policy stresses the need to sustain functional networks of representative terrestrial and aquatic ecosystems for the sustainable provision of multiple ecosystem services. Implementing this means that the complexity of interactions between social and ecological systems at multiple spatial scales and levels of governance needs to be understood. Place-based knowledge production and learning through integration of different research disciplines in collaboration with actors and stakeholders (i.e. transdisciplinary research) is a key feature to achieve this goal. Using a suite of local landscapes and regions on the European continent's West and East as a laboratory, we developed and applied a step-wise approach to produce knowledge and encourage learning towards functional green infrastructures. Our diagnoses of forest landscapes show that the functionality for wood production and biodiversity conservation was inversely related in the gradient from long to short forest management histories. In Europe's West there is a need for increased quantity of, and more functional, protected areas; diversification of management methods; and landscape restoration. In NW Russia there are opportunities to intensify forest management, and to continue the land-sparing approach with zoning for different functions, thus reducing biodiversity loss. Examples of diagnoses of social systems included the evaluation of comprehensive planning in Sweden, outcomes for biodiversity conservation of forest certification in Lithuania, and learning from environmental managers. We conclude that the main challenge for securing functional green infrastructure is poor cross-sectoral integration. Treatment of social-ecological systems requires knowledge-based collaboration and learning. The diversity of landscape histories and governance legacies on the European continent's West and East, including Russia, offers grand opportunities for both knowledge production about performance targets for green infrastructure functionality, as well as learning to adapt governance and management to regional contexts. Integrating project funding for both researchers and stakeholder collaboration is a necessary strategy to fill the transdisciplinary research agenda. However, formal and informal disciplinary and administrative barriers can limit team building despite self-reflection and experience.

Keywords: biodiversity, bio-economy, collaboration, ecosystem services, environmental history, gap analysis, governance, green infrastructure, habitat modelling, intensification, landscape approach, planning, stakeholder mapping, transdisciplinary, rural development.

Introduction

Natural capital, in terms of species, habitats and ecosystem processes, is the ultimate base for the provision of ecosystem services supporting human well-being. Today, the demands on what different ecosystems in landscapes are expected to deliver in terms of goods, functions and values is increasing. Intensified land and water use for production of wood, food, feed and energy results in loss and fragmentation of habitats for both wild species and humans in rural and urban landscapes. To satisfy multiple ecosystem services there is a need to maintain many types of land covers as functional networks. The EU policy concept green infrastructure captures this [25]. Examples of green infrastructure include different kinds of forests and other wooded land, grasslands, wetlands, rivers and streams, and urban green space. Working towards functional green infrastructures calls for the integration of sustainable use of ecosystems natural resources, protected area development and landscape restoration. This requires governance and management approaches, which integrate public, private and civil sectors at multiple levels in society, and treat landscapes as coupled social-ecological systems. Ecological, economic and socio-cultural sustainability pillars all need to be included into landscape governance and management. However, this is often neglected because individual sectors tend to focus on their own aspect of sustainability without sufficiently addressing conflicting objectives, or even avoiding making them visible.

The term landscape approach captures the need to develop locally and regionally adapted sustainable solutions in landscapes as social-ecological systems [20, 69, 70]. Landscape approach is about carrying out place-based transdisciplinary research with stakeholders. This requires (1) sufficient time to develop collaborative capacity among participants: "gyroscope" according to [53]; (2) existence of long-term data about the states and trends of ecological and social systems: "compass" according to [53]; and (3) sufficient coordination [5, 8]. A wide range of concepts aimed towards place-based knowledge production and engaged stakeholder collaboration have emerged. One such concept is the Long-Term Socio-Ecological Research (LTSER) platform [e.g., 45, 73]. Other examples are Model Forest [59] and Biosphere Reserve [22]. The focus in all of them is on continuous relevant knowledge production and learning towards securing sustainable landscapes.

The aim of this paper is to advocate the need for collaborative evidence-based knowledge production and collaborative learning about how to satisfy economic, ecological and socio-cultural dimensions of forest landscapes by combining evidence-based knowledge and collaborative learning. We summarise a decade of development and application of diagnosis and treatment of different green infrastructures, and their governance, planning and management toward functionality, in rural and urban landscapes [6–9]. First, we focus on concrete tools that can help facilitate evidence-based collaborative learning and decision making processes. For ecosystems these are regional gap analysis of green infrastructure supporting strategic planning, habitat suitability modelling supporting spatial planning, and habitat restoration. For social systems these are stakeholder mapping, policy implementation and horizon scanning. Second, we present examples of results from our research in regions with different forest landscape histories and landscape governance systems on European continent's West and East, such as in the Baltic Sea region and NW Russia. Finally, we discuss the barriers and bridges towards transdisciplinary research, developing cultures of collaborative learning, and introduction of problem-based learning in education.

Policy context

The dominant natural potential vegetation in most of the European continent is forest. Forests provide a range of goods, services and values that create opportunities to address many of the most pressing sustainable development challenges [84]. The gradual emergence of policy on sustainable forest management (SFM) reflects a transition from harvesting of forest in naturally dynamic forests and development of sustained yield wood production on the one hand, to also satisfying ecological and socio-cultural objectives on the other [33]. This increased complexity has resulted in the need to transition from single to multiple spatial planning scales within local administrative units and regions [8]. The policy term green (or ecological) infrastructure as a means of sustaining natural capital as a base for providing ecosystem services for human well-being captures this (Figure 1).

Currently, new policy objectives, such as forestry intensification for climate change mitigation have appeared [60]. This further complicates previous challenges of biodiversity conservation and rural development [13, 62, 63, 77]. Intensification, which links closely to terms like bio-economy, bio-based economy and knowledge-based bio-economy, is becoming a new influential forestry discourse. There are indications that the bio-economy discourse is beginning to dominate the previous sustainable forest management discourse, which simultaneously considers economic benefits, forest biodiversity conservation and rural development [66]. There are thus

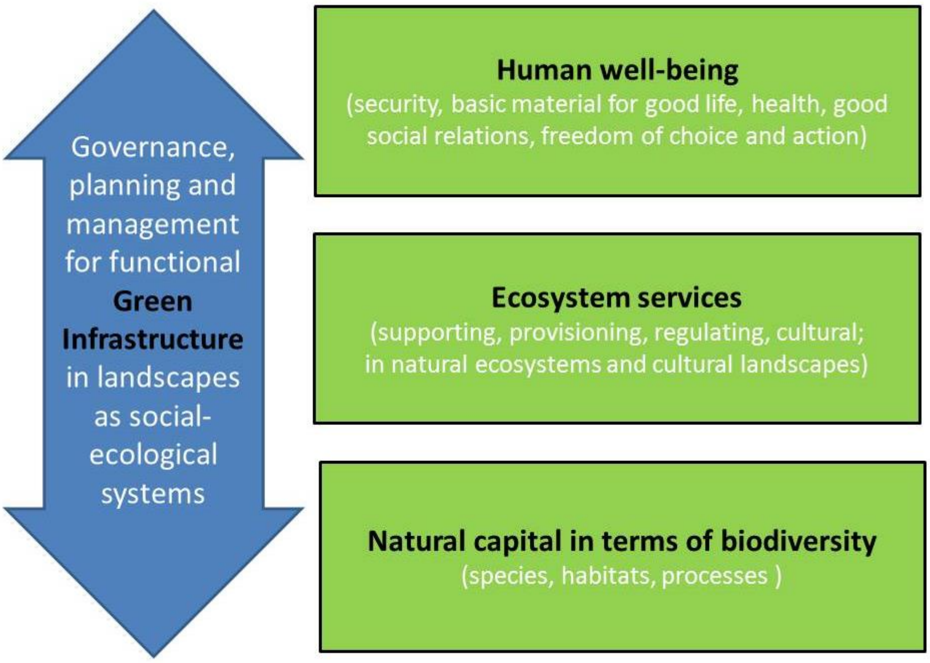

Fig. 1. The policy term “green infrastructure” [9, 25] conceptualizes the need to maintain sufficient amounts of representative ecosystems as functional networks by spatial planning. Green infrastructure is a tool towards delivering ecosystem services and human well-being

tensions between different SFM objectives; notably between increased production and extraction of forest biomass, and the contributions made by the same biomass to soil fertility, biodiversity and protective functions [14, 85]. Production of wood versus non-wood forest products in rural areas is another example [65, 77]. Translating SFM policy objectives into action on the ground is therefore described as a “wicked problem” [e.g., 30]. Thus, there is a need for new collaborative decision-making approaches towards sustainable use of forest goods, services and values [20, 70]. This stresses the need to assess the role of alternative forest value chains for economic, ecological and social dimensions of SFM in time and space [e.g., 63].

Methodology

A tool-box for diagnosis and treatment towards sustainable landscapes

To support knowledge production and learning towards functional representative habitat networks as green infrastructure in landscapes requires integration of academic and non-academic actors. This means that researchers representing humanities, social sciences and natural sciences, as well as stakeholders in the landscape, co-produce the knowledge needed to protect, manage and restore functional habitat networks [20]. The term transdisciplinary research captures this [2]. Viewing landscapes as individuals, we use a systematic case study approach (e.g., [42]) in seven steps [6] to “diagnose” green infrastructures as well as societal steering processes, and to identify “treatments” to maintain functional green infrastructures (Figure 2). Comparing landscapes, such in the Baltic Sea Region and NW Russia (Figure 3), which host regions and countries with different governance systems and landscape histories, is an innovative approach [5, 6, 8, 35].

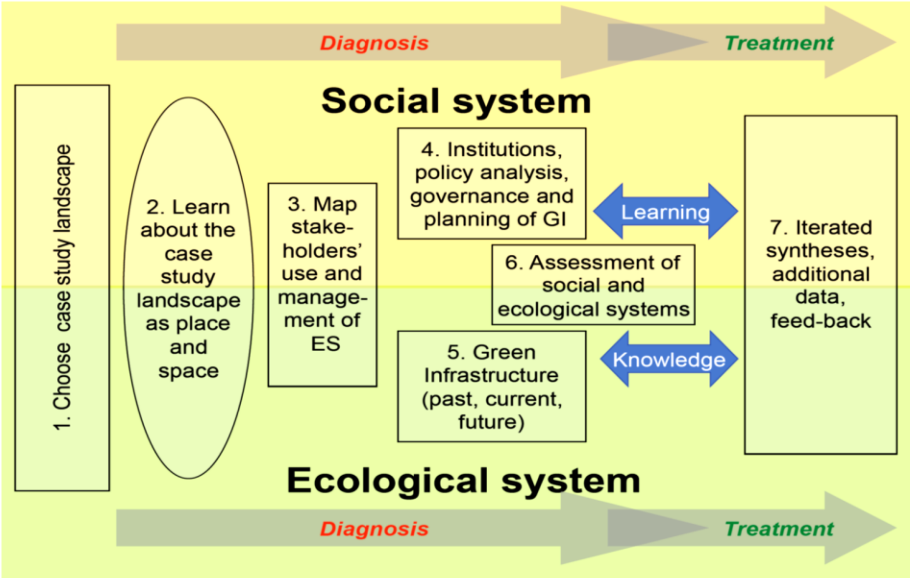

Fig. 2. Knowledge production and learning towards functional green infrastructure require a systematic approach [5, 8, 19]. For each landscape case study, both diagnoses and treatment are needed. Firstly, diagnoses of both the ecological system and the social system are made to understand barriers and bridges for a functional green infrastructure (steps 1–6). Secondly, treatment is provided in the form of knowledge production and social learning through analyses and visualization tools as a basis for integrated spatial planning by actors from different levels and sectors of society (steps 6–7)

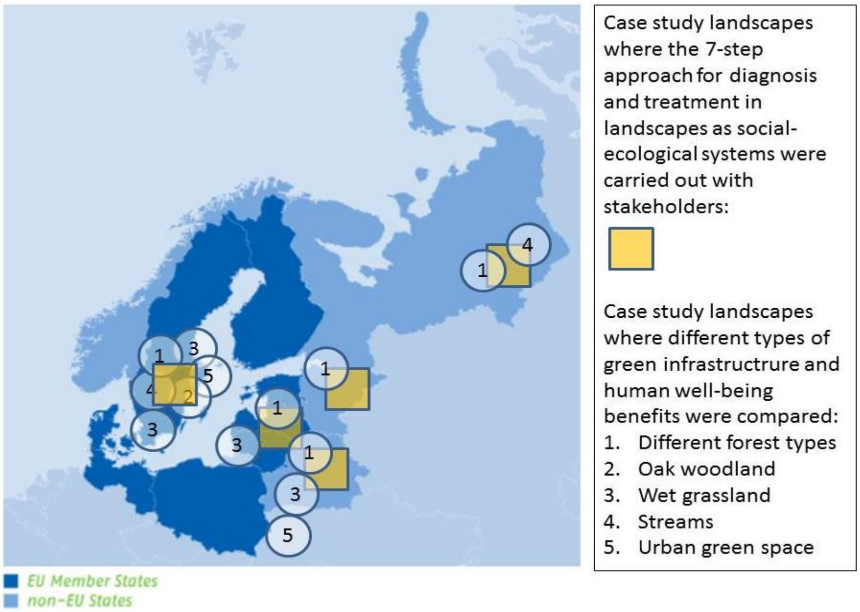

Fig. 3. The Baltic Sea Region and NW Russia in northern Europe's West and East hosts a steep gradient of landscape histories ranging from long to short, and with different approaches to governance and planning. This forms a valuable laboratory for knowledge production and learning towards sustainable forest landscapes [8, 9, 35]. Map from Interreg Baltic Sea Region (interreg-baltic.eu)

The ecological system

Gap analysis for strategic planning

The aim of a regional gap analysis is to present and apply an evidence-based systematic approach to support strategic planning towards learning for conservation, management and restoration of functional habitat networks as green infrastructure (e.g., [16]). This involves several steps. First, analyses are made of the transitions of representative types of potential natural vegetation to new land covers managed to derive human benefits. Second, the present amount of representative land covers is compared with what is needed to maintain natural biodiversity in the long term. This should be grounded on evidence-based knowledge about tipping points for how much habitat loss that can be accepted without losing species [3]. Third, the necessary amount of protected and other conservation areas to the current amount among representative land covers is estimated.

The results from quantitative gap analysis can then be fed into a hierarchical conservation planning processes (e.g., [3]). Once identified, gaps may be filled through new reserve acquisitions or designations, or through changes in management practices. The goal is to ensure that all ecosystems are represented adequately [71]. This involves (1) formulation of long-term strategic quantitative targets regarding the amount of areas to be allocated to land use that maintains natural and anthropogenic land covers that are not compatible with intensive forestry and agriculture (e.g., [79]), (2) development of tactical spatial planning about where action (protection, management and restoration) is needed based on analyses of the functionality of different types of set-asides as green infrastructure (e.g., [39]), and (3) operational execution of these plans by establishing set-asides with appropriate management, including allocation of required funding to carry out management, to compensate land users and owners for the limitations in land use that follow from area protection, how traditional village systems can be maintained, or to acquire land for conservation.

Habitat modelling for spatial planning

Habitat Suitability Index (HSI) modelling can assist tactical spatial planning towards maintaining functional habitat network. HSI-models combine empirical knowledge about focal species' habitat requirements using variables and parameter values for relevant land covers, digital land cover data, and a geographic information system (GIS) to run ecologically relevant spatial models (e.g., [57]). The focal species approach is a useful starting point for biodiversity conservation in that it provides explicit recommendations rather than general principles. This approach allows transparent spatially explicit predictions for the expected occurrence of particular species, such as resident woodland birds [43, 63]. Focal species modelling can be used to help predict the effects of land use change on habitat networks [48]. The creation of HSI models involves three main steps; (1) the selection of patches with suitable forest land covers, as required by the target focal species; for example a certain forest type with a certain age class and tree species structure; (2) removal of patches not satisfying the minimum areas required by the target focal species; and (3) identification of areas where patches are sufficiently concentrated to meet the species-specific critical thresholds at the landscape level [1]. This results in a probability map identifying areas where the focal species may be found.

Operational landscape and habitat restoration

The long-term focus of traditional forest management on high wood and biomass yields has resulted in a predominance of even-aged forest management in Europe’s West (e.g., [64]). This has simplified forest landscapes’ composition, structure and function, and has reduced the amount of habitats for both wild species and human well-being to low levels [37]. This calls for defining benchmarks for habitat and landscape restoration [56], and appropriate management methods be developed. For wild species emulation of natural forest disturbance regimes, to which species have adapted, is one approach to derive forest management alternatives (e.g., [44]). For studies of human well-being suitable survey-based approaches include semi-structured interviews with rural and urban citizens (e.g., [37]), and Discrete Choice Experiments (DCE) involving representative samples of a population as a means of defining the desired land cover types [86, 87].

The social system

Mapping of stakeholders

According to the Aarhus Convention [26] citizens can more effectively conserve the environment if they can rely on this convention's three pillars (i) access to information, (ii) public participation in decision-making, and (iii) access to justice in environmental matters. To identify key actors and stakeholders linked to a particular place or topic, one must consider all people or groups that are affected by, can influence, or may have an interest [31]. Stakeholder mapping can be done by a research team, but works better in collaboration with relevant organisations and local key informants, and should be carried out throughout the project to ensure key groups are included. Identification of stakeholders is an iterative process, for example by following a snowball sampling approach until no new stakeholders are identified. Stakeholders can then be grouped, for example as belonging to private, public and civil sectors; local, regional and national levels of governance; and having different levels of participation in in the topic at hand [36].

Barriers for policy implementation

To understand the extent to which a particular policy or norm is handled through governance, planning and management, one can define a normative model for how different societal actors should ideally act to implement policies (e.g., [24]. This can be applied to (1) the policy process, (2) to outputs (e.g., a planning process or management approach) or (3) the consequences the process has for the issue at hand (e.g., biodiversity conservation in terms of population viability) (see [67]). How does a particular policy take into account different stakeholders' realities and needs? Is the perspective rural or urban, or on goods, services or values? According to [55] there are three prerequisites need to be realised for the effective implementation of policies, say, through planning and management outputs. First, actors need to understand what is expected. This can be derived from policy documents and from existing scientific knowledge. Second, actors need to have essential resources (e.g., data, tools, staff, money). Third, they need to have the willingness to act. Finally, the consequences on the ground for economic, ecological and socio-cultural aspects of sustainability need to be assessed.

Horizon scanning for the future

Social science with a "phronetic (prudent) approach… is to carry out analyses and interpretations of the status of values and interests in society aimed at social commentary and social action, i.e. praxis…" [41]. This can be addressed through three questions: Where are we going? Is this desirable? What should be done? Horizon scanning for the future is an approach to address those questions. It is the formal process of gathering, processing and disseminating information to support decision-making in the future (e.g., [72]). Various methods exist and may comprise questionnaires, focus groups and workshops conducted in various forms but also use of issue trees, literature search, trend analysis and scenario planning [23, 78]. A horizon scanning is both an approach to begin the process of knowledge production and learning with stakeholder groups, and to interpret and discuss the results. By comparing stakeholders' perceptions with contents of policies, such as the United Nation's sustainable development goals [84], a "gap analysis" also for human well-being in rural and urban development contexts can be made.

Review of results

The ecological system

Gap analysis for strategic planning

Angelstam P. and Andersson L. [1] estimated the need for protected areas to maintain forest biodiversity in Sweden. Using habitat loss thresholds for long-term survival of specialised species in different forest types they estimated that, depending on the type of natural forest dynamic, the long-term need of protected areas ranged from 9 % in northern Sweden to 16 % in southernmost Sweden. No need for protected areas was assumed for forest environments that can be emulated by forest management that mimics natural forest disturbance regimes, which is more difficult for forest types typical for southern Sweden. A follow-up 10 years later [3] concluded that existing area of protected and set-aside forests is presently too small and with too poor connectivity. However, because the ideas about novel biodiversity-friendly forest management system aimed at mimicking natural forest dynamic (e.g., [44]) were never realised, the need of protected areas is actually higher [8].

As an example, a gap analysis was conducted for the Ukrainian Carpathians as the first attempt to provide a quantitative estimation of the needs to maintain green infrastructures represented by both natural forests and biocultural landscape values in this ecoregion [16]. The results clearly indicate two patterns. Regarding natural forests, loss of forest areas (especially lowland broadleaved forests), tree species replacement (Norway spruce monoculture forestry, and forestry intensification) are the key problems threatening forest naturalness. Regarding cultural landscapes, they are currently maintained as a result of the need for people in rural areas to secure their livelihoods by subsistence farming. For NW Russia, Kobyakov K. and Jakovlev J. [18] reported gaps and limited representativeness of the protected area network.

When performing gap analyses for biodiversity conservation it is crucial to have evidence-based knowledge about thresholds for how much habitat that is needed to maintain viable populations of species that represent different levels of specialisation and land covers. Research on land-use history and land cover change forms an important avenue to define benchmarks for green infrastructure maintenance, and to facilitate learning towards understanding the development trajectories of functionality of habitat patch networks. Manton M. and Angelstam P. [56] defined an approach to derive evidence-based knowledge about how much (amount, quality, and patch size requirements) habitat is enough to maintain viable populations of species. Using a representative example of the European landscape gradient between agricultural and forest landscapes in southern Sweden [58], they analysed the historic range of variability of the total area, quality, and size of grassland patches, and compared this to the requirements of focal grassland species. To develop evidence-based performance targets also for aquatic habitats, a suite of representative aquatic species needs to be analysed with respect to their qualitative and quantitative habitat requirements (e.g., [81–83]). In Sweden the application of aquatic gap analyses for fish species is enhanced due to available databases on fish and habitats (see [82]).

Habitat modelling for spatial planning

Manton M. et al. [57] applied Habitat Suitability Index (HSI) models using three different Swedish forest spatial land cover data sets. Results showed that this method is an appropriate way to gain insight into the functionality and connectivity of habitat networks. However, land cover data used must be carefully, evaluated and combined with other landscape information for effective conservation planning of particular forest stand types (e.g., [75]). Quality assurance through validation of HSI-models with independent field data is important [32].

Angelstam P. et al. [14] and Naumov V. et al. [63] used two types land cover data and a macroecological approach along the steep West-East gradient in the Baltic Sea Region and NW Russia to assess regional profiles of economic vs. ecological benefits delivered by forest landscapes. They found an inverse relationship between the opportunities for economic benefits based on intensive wood and biomass production on the one hand, and biodiversity conservation on the other (Figure 4).

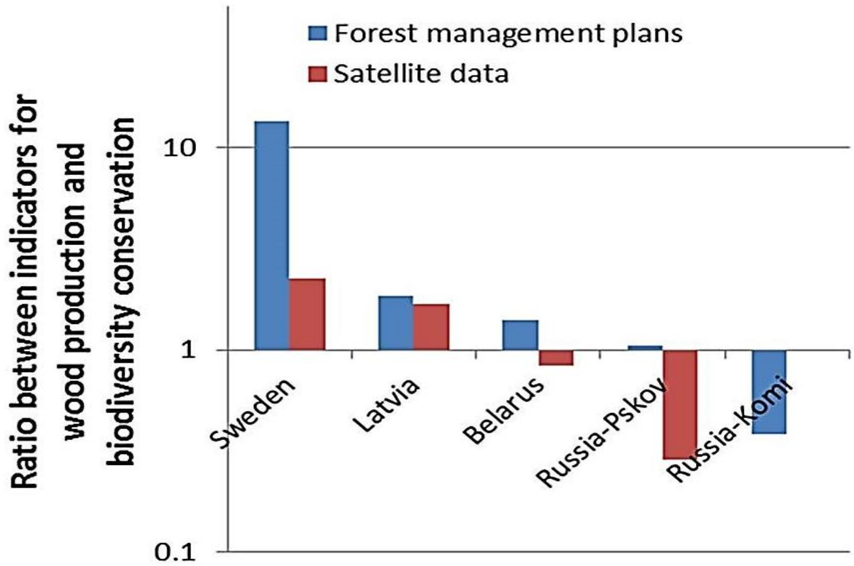

Fig. 4. Spatial data based on open access remote sensing [14] and forest management plans [63] showed that green infrastructures for wood production and biodiversity conservation, using for example resident birds as indicators, are inversely related among the case study regions. Therefore, while restoration for biodiversity conservation is needed in the West, intensified use of wood and biomass is possible in the East. However, a cautious approach should be applied because intensification of wood production threatens biodiversity

Study areas in NW Russia demonstrated the highest levels of biodiversity, whereas economic indicators were low. This can be explained by insufficient road network and undeveloped legislation that inhibit proper silvicultural treatments such as pre-commercial thinning [13, 61]. Comparing the contribution of voluntary set-asides within the framework of forest certification in Lithuania showed that formally protected areas were more important for green infrastructure than voluntary set-asides within forest certification [39]. Thus, HSI models are a tool that can help to resolve a wide range of barriers when managing landscapes for the maintenance of biodiversity.

Operational landscape and habitat restoration

Maintenance of functional habitat networks requires restoration at different spatial scales. A study at the landscape scale conducted in Fulufjället National Park located across the border between Norway and Sweden revealed that restoration of naturalness of forest habitats in the surrounding managed matrix is viewed as an economically viable option by citizens in both countries [87]. In contrast, results of the twin study conducted in the Bialowieza National Park located across the border between Poland and Belarus provided rather mixed evidence [86]. This was due to the considerable proportion of respondents preferring status-quo in terms of the protected area.

Operational stream restoration and riparian forest conservation management requires both a local perspective, and integration at the catchment level [80, 89] of water, forest, nature conservation and forest education actors [15]. Using a local stream section and an entire river catchment Törnblom J. et al. [82] developed evidence-based knowledge about the habitat requirements of brown trout, and applied this to local practical dam removal in the field to get practical experience and build trust and confidence between involved stakeholders. Students of a forestry BSc programme regularly take part in planning activities for forest management close to aquatic environments, and local concrete actions and demonstration sites evolved with the vision to make an entire river catchment into a landscape based laboratory of different study and demonstration sites of different collaboration initiatives in space and time. The impact of this study was scrutinized using system thinking approach [27].

The social system

Mapping of stakeholders

Governance includes structures and processes, through which stakeholders may make and implement decisions. Elbakidze M. et al. [36] compared Swedish (Vilhelmina and Bergslagen) and Russian (Komi and Pskov) Model Forest initiatives, and showed that the stakeholders encompassed all societal sectors, i.e., civil, private, and public. However, in three of the MFs, more than 40 % of stakeholders represented just one sector. In Bergslagen and Komi there was a balance between stakeholders at local to global levels. In Vilhelmina Model Forest, almost 50 of all stakeholders represented local-level stakeholders. Model Forest initiatives represent attempts to establish a new type of governance of forest landscapes in both the Russia and Sweden. In both countries stakeholders of the Model Forest initiatives had begun to develop a network-based type of governance system locally to internationally (e.g., [21]).

Barriers for policy implementation

As top-down approaches only cannot sustain forest goods, services and values in an effective way, new non-state-centred civil society and market oriented means of decision-making are emerging [46, 76]. Many studies describe new ways of governance that go beyond the centralised state [17, 46]. FSC certification is one example of an informal institutional governance instrument. At the policy level Elbakidze's et al. [39] study on FSC certification outcomes for biodiversity conservation in Lithuania shows that there was a clear mismatch between criteria and indicators related to biodiversity in the FSC standard and evidence-based knowledge. A key gap in the standard in Lithuania was the lack of any requirement to maintain connectivity of habitats. There are also context-specific differences in environmental policy implementation, both within and among countries. Henry L.A. and Tysiachniouk M. [47] showed that forest companies in NW Russia are more ecologically responsible than those in the Russian Far East. This regional variation is explained by different levels of biodiversity, proximity to markets that are not sensitive to FSC certification and different degrees of penetration by multi-national companies. A comparison of the Russian and Swedish FSC standards by Elbakidze M. et al. [34] showed that the Russian standard included indicators for all spatial scales of biodiversity conservation (tree, stand, landscape, ecoregion) while the Swedish mainly on stand and tree scales. Additionally, set-aside areas for biodiversity conservation in Sweden were two orders of magnitude smaller than in Russia, had much lower structural and potential functional connectivity and were located in a fragmented forestland holding.

Spatial planning is a necessary tool to integrate economic, ecological, sociocultural policy agendas. Regarding planning processes, as shown by Blicharska M. et al. [24] about biodiversity conservation including stakeholder participation in Poland, planners had insufficient knowledge about both those topics, limited resources and tools for planning of functional habitat networks and collaboration, poor connections between local and regional planning, and limited public participation. The key problem was related to planners' ability to act. In Sweden, comprehensive planning by municipalities aims to steer territorial development and help to solve conflicts among different interests. Also in the Swedish Bergslagen region, planners experienced difficulties to integrate different topics and engage stakeholders in long-term spatial planning [38]. Supplying data about the state and trends of different dimensions of sustainability is one way forward [19].

Blicharska et al. [24] also showed that participation in planning can be a challenge. The Aarhus Convention [26] and the Access to Environmental Information Directive [28] and the INSPIRE Directive [29] together create a legal foundation for the sharing of environmental information between public authorities and with the public in EU countries. However, implementation takes time. In Poland for example, according to The Environmental Implementation Review (EIR) (EU, 2017) not all spatial information needed for the evaluation and implementation of EU environmental law in Poland has been made available or is accessible on the INSPIRE geoportal. However, Poland has taken steps to centralise information about the data (i.e. metadata) using the national geoportal (geoportal.gov.pl) and reforming the public environmental data policy, aiming for a higher level of transparency and the larger part of this missing spatial information is available under this service. At the same time the Environmental Implementation Review show that Sweden's performance on the implementation of the INSPIRE Directive as enabling framework to actively disseminate environmental information to the public is good, but needs some improvement in the part of accessibility of missing documented spatial data sets 'as is' to other public authorities and the public through the digital services.

Horizon scanning for the future

Here we present two examples of wicked problems, viz. large carnivore conservation at the expense of the rural population, and reconciling intensive forest management, biodiversity conservation and nature-based tourism.

Centralized management of large carnivore populations in rural and remote landscapes used by local people often leads to conflicts between the objectives of wildlife conservation and rural development. The return and recovery of wolf populations in Scandinavia is an example where the wolf's ecological needs for suitable habitat and prey may be satisfied [54, 88]; but where the social and economic pillars of the sustainability concept in rural settings are neglected [40, 50, 74]. In Norway, recovery the wolf population have been politically decided at the international and national levels, but needs to be put into force and tolerated locally on privately owned property in rural and remote areas [49]. This may have economic costs to the rural population. The assumed mechanism is that hunters fear that their economically and culturally valuable hunting dogs may be killed by wolves [52], which results in reduced hunting and thus reduced revenues for the landowners. It is important to note that while the economic impacts of wolves may be compensated where governments have the will and the economic resources, the impacts on the lifestyles of rural people (e.g., hunter's fear of losing prized dogs to wolves) will remain controversial. Acknowledging these economic and social consequences of hosting wolves is important for successful wolf conservation.

Evoked by international policy developments, and a national strategy for long-term sustainable land use, Sweden developed a national forest programme in 2016 – 2018 that aims at increased wood and biomass production, biodiversity conservation and rural development. However, this involves conflicts between different types of use of forest landscapes at multiple scales. It also affects the portfolios of ecosystem services that can be delivered in a particular forest area. Laxå municipality in the informal Bergslagen region is a good example with most forests aimed at wood and biomass production [12]. During spring 2017, Laxå pronounced itself as an "ecotourism area". The assets are the forests in the southernmost boreal forest massif in Sweden, and with Tiveden National Park as the focal area for nature-based tourism. How to plan for and satisfy different interests are key issues. Following the Model Forest concept's recipe of partnership towards sustainability in a landscape, "Collaboration Tiveden" was established. It represents the municipality Laxå, the state forest company Sveaskog, and local tourism businesses. The focus is on how to use a 20 square km "buffer zone" on Sveaskog's land around Tiveden National Park to develop other forest management methods than the prevailing clear-felling systems. The aims are to learn what visitor-friendly forestry methods involve, and to include both traditional and new forest benefits into spatial planning.

Discussion

Mutual learning for sustainable forest landscapes

Achieving sustainable development as an inclusive societal process, which results in sustainability and resilience on the ground in the relationship between human societies and the natural environment in real-world landscapes is a grand challenge. Comparing NW Russia and Sweden Nordberg M. et al. [64] showed that challenges and experiences are in some cases very different, and in other cases very similar. Thus, there is opportunity for mutual learning. This is emphasised by the fact that forestry is a global business, both in terms of trade and concerning international agreements, including conservation planning. Regions in different stages and trajectories of development can learn from each other to improve their approaches to forest governance, planning and management [4]. Border regions, such as between EU and non-EU countries are particularly interesting [11, 87].

To encourage the necessary collaborative learning among actors and stakeholders, there is a need to develop integrated place-based partnerships involving all key players across different sectors at multiple levels in local landscapes that matter to people living there. The term landscape approach captures this, and focuses on strengthening cultures of maintaining inclusive social processes on the one hand,

and sharing different actors' and stakeholders' views and needs of what multi-functional landscapes and regions should satisfy and how to accomplish that on the other. "Partnership towards sustainable landscapes", such as defined by IMFN [59] is one type of landscape approach that is applied globally, and with initiatives in both Sweden and NW Russia [21, 36].

The European continent's West and East form a 'time machine', which provides unique potential for mutual learning towards multi-functional landscapes and regions through collaborative learning. This is possible due to the steep gradients in land use history whereby the gradual exploitation and intensive management of forest resources has spread like a tidal wave from areas of high demand in the West to more and more remote regions in the East. Similarly, there are large regional differences in governance arrangements and social and cultural capital.

The contrast between landscape histories, land ownership, legacies of governance/government, cultural meanings and socio-economic situations, such as in the Baltic Sea Region and NW Russia, is the ideal base for twinning between regional clusters of rural landscape stakeholders towards locally and regionally adapted solutions. However, a key challenge is to determine the effectiveness of different approaches to maintain multi-functional landscapes. One dichotomy is the societal culture of land-sharing, which believes in wood/fibre/biomass/food commodity production is compatible with social and cultural sustainability as well as biodiversity conservation across the entire landscape; and land-sparing, in which intensive land use is segregated from multiple-use and protected area networks as functional green infrastructure. While land-sparing is not popular in the West, it is indeed supported by evidence-based analyses across the world, and has been applied through zoning forest landscapes for different purposes in for long time in today's Russia [62]. This means that social innovations that facilitate learning need to be encouraged in landscapes as social-ecological systems [21].

Environmental history and landscape as tools for integration

Implementing policies aiming at sustainable forest landscapes requires that the history and contemporary states and trajectories of forest landscapes, including both their biophysical, anthropogenic and intangible interpretations are understood [10]. As an interdisciplinary field of research, environmental history is an appropriate framework for studying the dynamics of landscapes as social-ecological systems. Worster's [90] environmental history framework is very useful when embarking on transdisciplinary research with stakeholders in a geographical area as space and place: (1) natural environments of the past, (2) human modes of production, and (3) ideology, perceptions and values.

Research on biophysical change of ecosystems is a crucial avenue to generate knowledge and facilitate learning about benchmarks for green infrastructure maintenance, understand the deviation from such benchmarks, and develop trajectories of habitat patch networks' functionality [51]. Comprehending the biophysical developments of a landscape and its habitat network can be achieved by using a time series of either or both spatial data and statistical data to determine spatial pattern (e.g., habitat amount, alteration, fragmentation and connectivity [56]), and altered processes affecting the functionality of a habitat network (Figure 5). Another approach is to compare contemporary landscapes with different histories [14, 63].

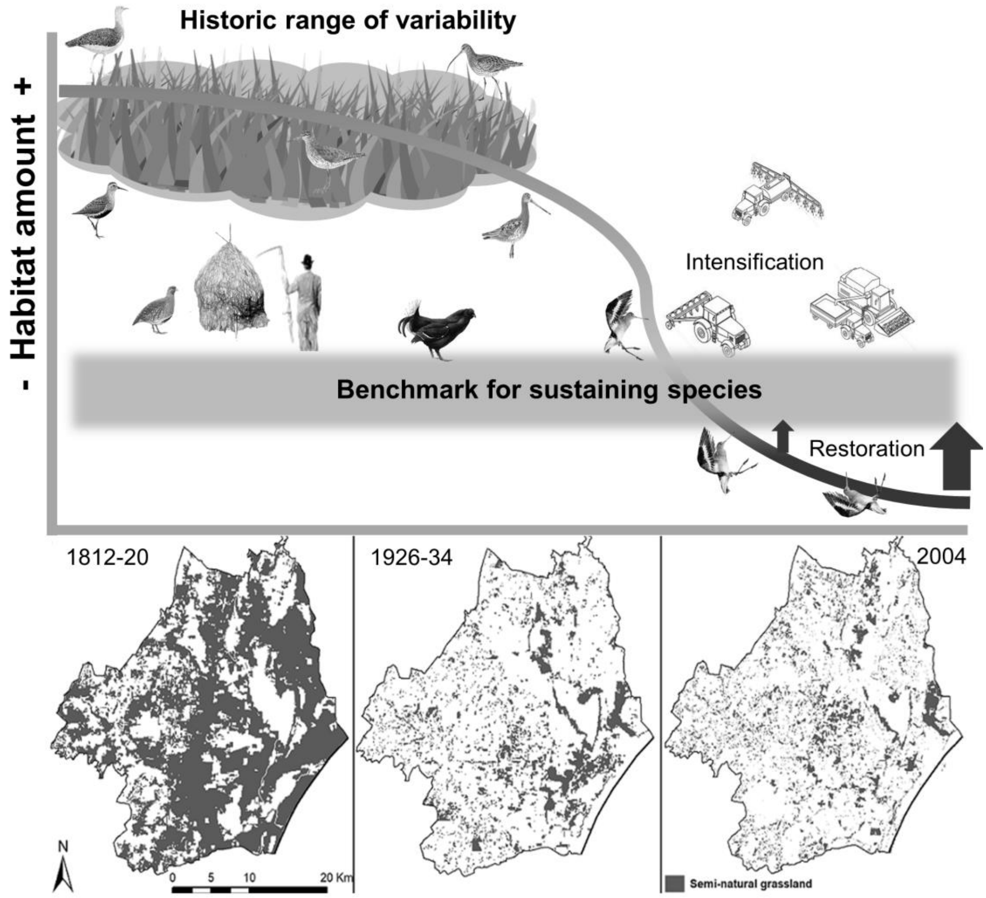

Fig. 5. Example of the historic range of variability of semi-natural grasslands in the Kristianstad Vattenrike Biosphere Reserve in Sweden presented in Manton M. and Angelstam P. [56]. This figure shows how data on the historic range of variability of a particular land cover and evidence-based knowledge about threshold interval for local extinction due to habitat loss can be combined to derive benchmarks as targets for landscape restoration and spatial planning towards a functional green infrastructure. The grassland cloud at the top represents the range of historical variability. The benchmark area illustrates the proportion of the historical range of variability that forms the benchmark level required for ecological sustainability. The grey line indicates the change over time in the amount of semi-natural grassland within Kristianstad. The three maps represent the three-time periods and show the loss and fragmentation of semi-natural grasslands over 2 centuries from 1812 to 2004. Finally, the arrows represent the need for landscape restoration and the need for pro-active spatial planning towards land-sparing. This study exemplifies this general approach using semi-natural grasslands and avian umbrella species. Illustration by M. Manton

To understand the proximate mechanisms behind biophysical landscape change it is important to consider the human technologies and ways of organizing production through land management strategies (including land abandonment) that have transformed natural systems. To identify the main actors that shaped the landscape, using a local area in the Komi Republic in Russia as a case study, Naumov V. et al. [61] reviewed literature about forest history, statistical reports, forest management plans and archive documents. To collect information about local stakeholders they employed focus group interviews as qualitative method to understand opinions and extract knowledge about societal barriers to intensification of forest management. In parallel, Stryamets N. [76] studied the governance of non-wood forest products, the production of which is negatively affected by forestry intensification. Interviews with 70 stakeholders from different sectors and levels of governance showed a shift from top-down government to a multi-stakeholder form of governance. This was legitimised by informal institutions, such as the FSC forest certification standard, and by formal institutions on the level of the Komi Republic. Another example is landscape restoration. This is important to maintain functional green infrastructures [56]. Dawson L. et al. [27] analysed the causal structures underlying governance and management of landscape restoration in Sweden. Key solutions were to secure institutional flexibility, timely availability of sufficient funds, and effective learning and knowledge production processes.

Ideologies are linked to values and perceptions, which influence political and economic life of society. Naumov V. et al. [61] analysed the ideologies behind forest landscape changes was made using data from literature review, interviews and focus group discussions. The focus was on understanding (1) what interests different actors and stakeholders pursued, (2) what values the forest management decisions promoted, and (3) what market structures dominated in the study period.

Transdisciplinary research problem-based learning

Knowledge about both social and ecological systems is a necessary but insufficient criterion for the development of sustainable forest landscapes. Knowledge must also be co-produced in real world conditions with governors, planners and managers to help dissolve barriers and provide real solutions [82]. For ecosystems, a set of specialized species and knowledge about their habitat requirements is an effective tool [68]. Analogously, for social systems, the needs of different stakeholder groups must be understood, and good governance developed. This stresses the need for social sciences that complements natural science by discussing values and goals [41].

The diversity of landscape histories and governance legacies among regions and countries representing Europe's West and East offers grand opportunities for both knowledge production about habitat loss thresholds for green infrastructure functionality, and learning to adapt to regional contexts regarding different ecosystems, landscape histories and legacies of governance and land ownership [6]. The necessary transdisciplinary research process requires (1) avoiding disciplinary formal and informal control, (2) integrating project funding to fill the transdisciplinary research agenda, (3) engaging key stakeholders, and (4) long-term team building based on self-reflection and experienced leadership [2].

One approach to supporting this would be a transdisciplinary research school for PhD students, post-docs and junior researchers, which can support problem-based learning using real world landscapes as laboratories. Communication and dissemination will bring the research school idea to the research community, and to actors and stakeholders in private, public and civil sectors. The research school could be used to share knowledge on how to (1) craft peer-review publications, (2) design research and data collection, (3) write competitive research proposals, and (4) how to establish landscape approach laboratories by (i) integrating researchers from different disciplines, (ii) analysing quantitative and qualitative data, and (iii) engaging stakeholders in knowledge production and learning. This approach would support development of a new generation of young professionals capable to analyse complex sustainability problems, of knowledge transfer, and of integration of academic and non-academic partners towards sustainable rural development in Europe.

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ПОЛУЧЕНИЕ НОВЫХ ЗНАНИЙ И ОБУЧЕНИЕ В СФЕРЕ УСТОЙЧИВЫХ ЛЕСНЫХ ЛАНДШАФТОВ: ЗАПАД И ВОСТОК ЕВРОПЫ КАК ЛАБОРАТОРИЯ

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В целях поддержания благоприятной для человека среды зеленая (экологическая) инфраструктура должна обеспечивать функционирование наземных и водных экосистем для экологически безопасного и рассчитанного на длительную перспективу получения от них разнообразных полезностей (экосистемных услуг). Сложность взаимодействия социальных и экологических систем в пространственных масштабах и на разных уровнях управления требует понимания. Ключевым фактором в достижении этой цели является получение новых знаний и обучение на местах за счет объединения различных исследовательских дисциплин при сотрудничестве всех заинтересованных сторон (т. е. проведение междисциплинарных исследований). Используя ландшафтные зоны регионов на западе и востоке Европы в качестве лаборатории, мы разработали и применили пошаговый подход к получению новых знаний и поддержке обучения в отношении функционирования зеленой инфраструктуры. Наш анализ лесных ландшафтов показывает, что обеспечение заготовки древесины и сохранение

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биологического разнообразия плохо совместимы с точки зрения лесоустройства. На западе Европы существует потребность в увеличении количества охраняемых территорий, диверсификации методов управления и восстановлении ландшафтов. На северо-востоке России есть возможности для интенсификации лесопользования и применения сберегающего земледелия, которое предусматривает районирование, позволяющее сократить потери биологического разнообразия. Примеры диагностики социальных систем включали оценку комплексного планирования в Швеции, результаты сохранения биоразнообразия в рамках лесной сертификации в Литве и обучение инженерами по охране окружающей среды. Основной проблемой в обеспечении функционирования зеленой инфраструктуры является слабое межотраслевое взаимодействие. Взаимодействие с социально-экологическими системами требует внедрения наукоемкого сотрудничества и обучения. Разнообразие ландшафтных изменений и практика управления на западе и востоке Европы, включая Россию, открывают широкие возможности как для получения знаний о целевых показателях функционирования зеленой инфраструктуры, так и для обучения в целях адаптации управления к региональным условиям. Интегрированное финансирование проектов, предполагающее сотрудничество ученых и групп заинтересованных лиц, необходимо для проведения успешных междисциплинарных исследований. Тем не менее, формальные и неформальные дисциплинарные и административные барьеры могут ограничивать их коллективную работу, несмотря на проведенный анализ и опыт исследования.

Ключевые слова: биоразнообразие, биоэкономика, сотрудничество, экосистемные услуги, экологические изменения, анализ разрывов, госуправление, зеленая инфраструктура, моделирование среды обитания, интенсификация, ландшафтный подход, планирование, определение круга заинтересованных сторон, трансдисциплинарность, развитие сельской местности.

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