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Tradition as asset or burden for transitions from forests as cropping systems to multifunctional forest landscapes: Sweden as a case study

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ABSTRACT

Expectations of what forests and woodlands should provide vary among locations, stakeholder groups, and over time. Developing multifunctional forests requires understanding of the dynamic roles of traditions and cultural legacies in social-ecological systems at multiple levels and scales. Implementing policies about multifunctional forests requires a landscape and social-ecological perspective, and recognition of both spatial and temporal features at multiple scales. This study explores the dissemination of even-aged silviculture in central, eastern and northern Europe, and the consequences of choosing different vantage points in social-ecological systems for mapping of barriers, and to identify levers, towards multifunctional forest landscapes. Using a narrative approach, we first summarise the development of even-aged silviculture in four European regions. Next, we focus on Sweden as a keen adopter of even-aged silviculture, and identify levers at three groups of vantage points. They were (1) biosphere with biodiversity as short-hand for composition, structure and function of ecosystems, which

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support human well-being at multiple scales; (2) society in terms of different levels of stakeholder interactions from local to global, and (3) economy represented by value chain hierarchies and currencies. The emergence of even-aged silviculture >200 years ago formed an expanding frontier from central to northern Europe. Sustained yield wood production and biodiversity conservation encompass different portfolios of ecosystem aspects and spatio-temporal scales. Ignorance and lack of knowledge about these differences enforce their mutual rivalry. An exploratory review of six groups of stakeholders at multiple levels in the traditional industrial forest value chain highlights inequalities in terms of distribution of income and power across different levels of governance. This effectively marginalises other than powerful industrial actors. The distribution of financial results along the value chain is dynamic in space and time, and not all benefits of forest ecosystems can be measured using monetary valuation. There are also other currencies and incentives. A discussion of cultural trajectories in central and eastern European, Russian and Swedish forest management illustrates that forest history patterns repeat themselves. Longitudinal case studies of countries and regions can help foster holistic multi-dimensional and multi-level systems thinking. Application of deep levers of change is likely to require external drivers. A key challenge is to handle the manufacturing of doubt and decay of truth, i.e., the appearance of alternative facts, and the diminishing role of evidence and systems analyses in political and civic discourses. This transition is fuelled by new and rapidly evolving digital arenas.

1. Introduction

Across multiple social-ecological contexts, based on forests, woodlands and trees, a wide range of land uses, landscape management and governance systems has developed to provide livelihoods for rural people, raw materials for wood-based value chains, and existence values. These practices are often based on both long established cultural traditions, and firm ideologies and manifestations for desired gains (Puettmann et al., 2009). Emphasis on different portfolios of benefits from landscapes with forests and trees change over time, and form different trajectories that are visible along environmental history gradients that have developed since the industrial revolution on the European continent (e.g., Naumov et al., 2018; Angelstam et al., 2021a). The meanings of terms like sustainable forests, sustainable forestry and sustainable forest management (Hölzl, 2010; Forest Europe, 2015) are thus dynamic in time and space (Lehtinen et al., 2004). With the increasing human footprint on ecosystems (e.g., Felton et al., 2020), forest landscapes illustrate that the demands for benefits may exceed the capacities of providing them (Beland Lindahl et al., 2017). This represents a wicked problem (Nikolakis and Innes, 2020), which requires new knowledge production, to learn new things, and abandon dearly held habits of thought and routines (Camia et al., 2021).

Implementing policies on sustainable development and sustainability concerning the governance and management of forests, woodlands and trees requires a landscape perspective including biophysical, anthropogenic and percieved dimensions (Angelstam et al., 2013), and spatial extents also beyond stands and forest management units (e.g., IUFRO's (2015) Strategy 2015–2019 "Interconnecting Forests, Science and People"). The Convention on Biological Diversity's ecosystem approach (https://www.cbd.int/decision/cop/?id=7148) and landscape approach (World Forestry Congress, 2009) emerged as a means to encourage a holistic approach stressing the importance of social-ecological system perspectives (Axelsson et al., 2011; Sayer et al., 2013; Arts et al., 2017; Angelstam et al., 2019). Current debates about what sustainable forest management vs. bioeconomy is (Pülzl et al., 2014; Bugge et al., 2016), and the rivalry among different stakeholders for benefits of forest landscapes (e.g., Birner, 2018) calls for systems analyses defining both shallow and deep leverage points for policy cultures, governance and management (Meadows, 2008/2015). Deep leverage points representing the mindset or paradigm on which a system is built are often inert, and fundamentally cultural (Inglehart, 2018). The discourse on multifunctional forests encompasses biodiversity dimensions like species as components, habitat as structures, and processes as functions in ecosystems, and increasingly also ecosystem services including cultural aspects and forms, and climate mitigation and adaptation (e.g., UN, 2015; Parviainen, 2015; European Commission, 2021; IPCC 2021), but also cultures of traditional practices and relationships (Stephenson, 2008). Cultures of forest and woodland management systems associated to professional guilds and sectors (Lawrence, 2006) may present both barriers and bridges to implement sustainable development as regionally adapted participatory collaborative social processes to exercise landscape stewardship (Bieling and Plieninger, 2017), which is necessary for developments towards landscape sustainability of different types as consequences on the ground. The conflict between even-aged silviculture and multifunctional forest landscapes is also a temporal conflict, since the social and economic processes related to forest management perform differently over time. A sociology of time is therefore a necessary element in these explorations.

The term sustainability (*Nachhaltigkeit* in German) is thought to have been coined by von Carlowitz (1713), and referred to securing the long term supply of wood for mining and booming industries in Germany (Carlowitz and Rohr, 2012). The culture of even-aged forestry system that this created in Europe to counteract forest loss and degradation, and cope with increased demands for wood, was then disseminated (Cotta, 1817). The "Normalwaldmodell" is still a foundation of sustained yield forestry (Mantel, 1990; Puettmann et al., 2009), and the associated "Forsteinrichtung" terminology that developed since the second half of the 18th century (see Nieuwenhuis, 2010). However, as reviewed by Ciancio and Nocentini (2000) this practice of forestry is challenged by the emergence of sustainable forest management policy since the 1990s, the implementation of which stresses the complexity of ecological and social systems, systems thinking and non-linearaties (Holling, 1978; Messier et al., 2013; European Commission, 2021). Given the awareness of declines of rural hinterland regions (Chiasson et al., 2019), insufficient green infrastructure for biodiversity (Svensson et al., 2019; Angelstam et al., 2020) and climate change (Rummukainen, 2021; IPCC 2021), the focus on bioeconomy and argumentation for forestry intensification has created a heated debate. Being a success story in terms of sustained yield wood production, in this study we use the forest landscape history of Sweden, including external drivers, as a case study of a conflict-laden context for forest culture evolution (e.g., Westholm et al., 2015; Mårald et al., 2017, Fischer et al., 2020; Sténs and Mårald, 2020). As demonstrated by Teplyakov et al. (2000) and Jakobsson et al. (2021) contemporary forest conflicts involve people with diverse portfolios of values, emotions and opinions. However, empirical evidence-based knowledge is not necessarily involved, or cherry-picked, and conflicts on forest issues may instead be driven by opinions (cf. Shiller, 2019), and manufacturing doubt (Bramoullé and Orset, 2018).

The aim of this study is to explore the gradual introduction of even-aged silviculture in parts of Europe, and the consequences of choosing different vantage points in social systems for mapping of barriers and identification of levers towards multifunctional forest landscapes. First, we summarise the frontier of even-aged silviculture that emerged in the German-Czech Ore Mountains, and then spread to other parts of today's Germany as well as to the Austria-Hungarian Empire, including the Ukrainian Carpathian Mountains, to NW Russia, and to Sweden.

Especially in the 20th century, the model was also exported to other continents (Puettmann et al., 2009). Second, viewing even-aged silviculture as a human culture (e.g., Ciancio and Nocentini, 2000; Knize and Romanyuk, 2006; Puettmann et al., 2009), with Sweden as a case study, we use multiple vantage points of social-ecological systems to identify different perspectives on current policies advocating multifunctional natural forest and cultural wooded landscapes (Angelstam et al., 2021a). Finally, we discuss a suite of deep levers towards transformative change regarding how natural forest and cultural woodlands can be sustained as multifunctional forest landscapes.

2. Methodology

2.1. *Forest landscapes as social-ecological systems in time and space*

As a theoretical framework supporting a systems perspective on landscapes as inter-linked human and nature systems, we chose social-ecological system (SES) (e.g., Partelow, 2018). This is a comprehensive and multi-tiered conceptual framework for diagnosing ecological system pattern and processes across scales, social systems focusing on governance interactions at multiple levels, and outcomes in social-ecological systems with a focus on their sustainability (Berkes and Folke, 1998; Ostrom, 2009). As a mainstream field of research, the SES concept has evolved into a systematic approach to understand how different SESs can be sustainable for people in places with different natural resource systems and spatial units, governance systems and actors. Within these main tiers, interactions and outcomes of SESs in various socio-economic and political contexts can be diagnosed (Partelow, 2018) through the lenses of the biosphere, the society and the economy as nested systems (Fig. 1), and over time.

2.2. *A transdisciplinary narrative approach*

In the context of implementing policies towards sustainable multi-functional landscapes including the biosphere, society and economy at multiple spatial scales and levels of governance, the team of authors shares a common interest in diagnosing and treating forest and woodland landscapes as social-ecological systems. In contrast to a disciplinary or sectoral approach, each author in this study brought their own academic and non-academic experiences and expertise (Table 1). The work with this article commenced with PA, SBN and LÖ agreeing in June 2019 to gather a diverse group of stakeholders interested in understanding how the heated debate about forests in Sweden appeared, and could be eased. This was followed by an open-ended workshop held August 5–6, 2020, and an ongoing lively broad mutual learning process by e-mail and on-line meetings. To track the historic knowledge transfer beginning in the 18th century about sustained yield even-aged silviculture from Germany to other countries on the European continent, an international team was recruited. Following the approach used by Angelstam et al. (2017) for ecological infrastructure in South Africa, this study can thus be viewed as an outcome of a transdisciplinary process, which integrates academic and non-academic participants' (Table 1) co-production of new knowledge through a learning process (see Hirsch Hadorn et al., 2008). Perspectives and knowledge were compiled, analysed and synthesised through the iterated process of producing a perspective manuscript by applying the criteria of being context-based, pluralistic, goal-oriented and interactive (Norström et al., 2020).

2.3. *Summary of four forest management transitions*

The effects of forest landscape transformation involve patterns like

Table 1
Characteristics in terms of representation of sectors at multiple levels of the diverse international team of authors, often matching several attributes (e.g., civil servant and researcher, forest owner and civil sector, and researcher and forest owner).

	Civil sector	Private sector	Public sector	Academia
International level	2	1	1	11
National level	3	4	1	6
Regional	1	0	1	4
Local level	2	7	0	2

Fig. 1. Dimensions of sustainability organised by the dependence of social systems on the biosphere, and relevant sustainable development goals (UN, 2015) (Illustration from https://www.stockholmresilience.org/images/18.36c25848153d54bdba33ec9b/1465905797608/sdgs-food-azote.jpg).

habitat fragmentation and loss (e.g., Angelstam et al., 2021a) and processes that alter natural disturbance regimes (Kuuluvainen et al., 2021), and take long time to develop. Different regions are therefore in different phases of this development (Naumov et al., 2016), as well as regarding the portfolios of desired forest benefits and types of value chains. The Pan-European diversity of forest and woodland management trajectories is rich. This allows for a "replacing time with space" natural experiment approach (e.g., Diamond, 1986; Angelstam et al., 2013) supporting knowledge production and learning about how to sustain multifunctional landscapes through multiple studies place-base case studies across the European continent as a "time machine" (e.g., Angelstam et al., 2013, 2021ab). Tracking the emergence and spread of the even-aged "normal forest" paradigm, we summarise the development of different forest and woodland management cultures in four case studies. These are the Ore Mountains in Germany and the Czech Republic, the Ukrainian Carpathian Mountains, NW Russia and Sweden, the last of which has become one of the most effective countries in the strive for intensive wood production and wood-based value chains (Fig. 2).

2.4. Three vantage points of forest and woodland landscapes

Viewing forest and woodland landscapes as social-ecological systems, temporal developments towards multifunctional landscapes need to encompass (1) multiple forest values in the biosphere, (2) stakeholders interactions and degrees of power in societies, and (3) economic value chain hierarchies and currencies (Fig. 2). Each of these three dimensions - representing nested and overlapping systems - offers vantage points for analyses.

(1) Biosphere's composition, structure and function across scales.

Forest landscapes provide multiple types of Green Infrastructure and profiles of nature's benefits (Fig. 3, left). First, we illustrate how different combinations of ecosystem attributes and spatial scales can be related to different levels of ambition for biodiversity conservation and sustainable forest management. Next, inspired by Puettmann et al. (2009:90), for the boreal forest which is the dominating land cover in Sweden, through the lenses of a forest manager and an ecologist, we contrast what characterises a naturally dynamic landscape versus a

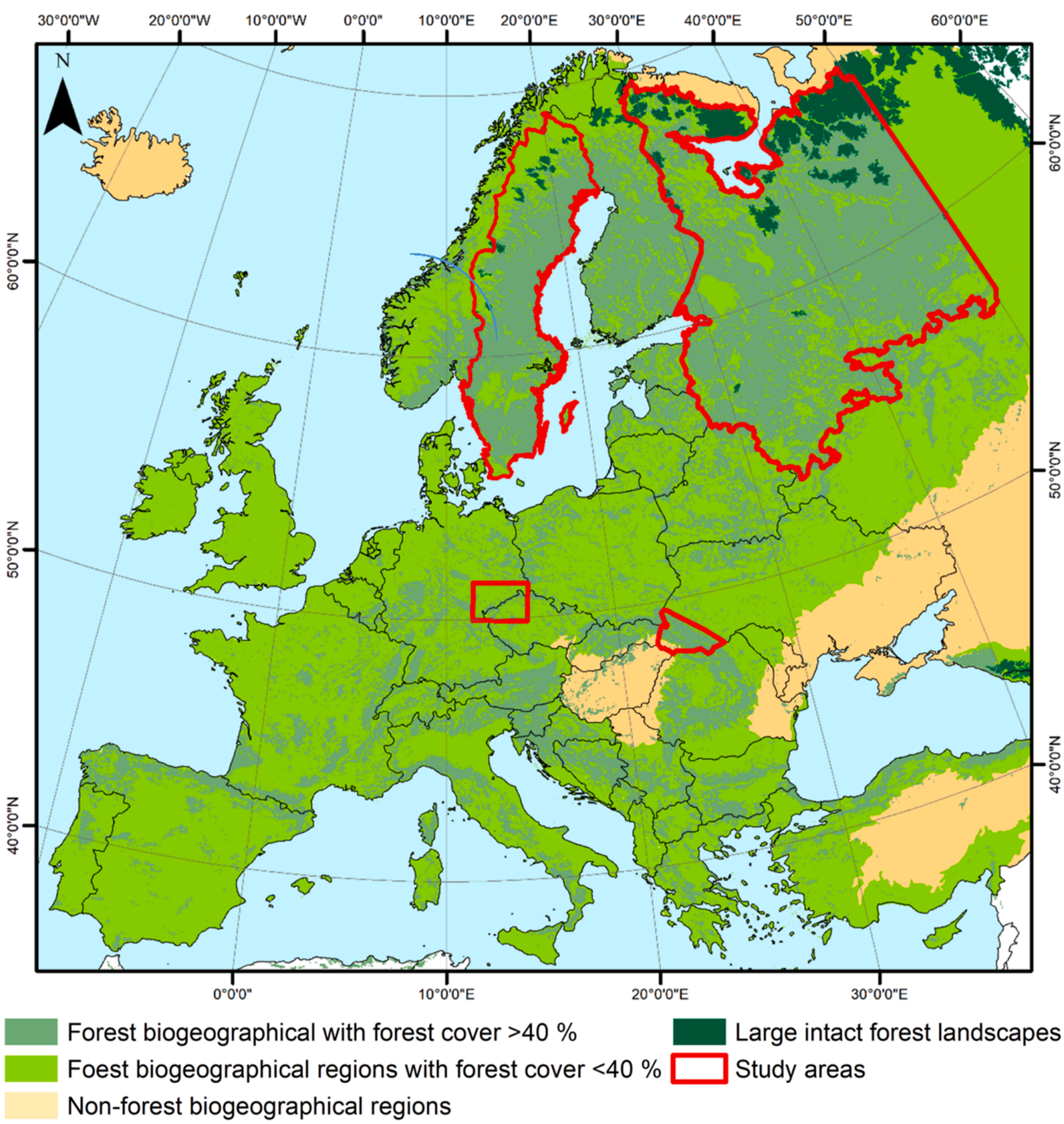

Fig. 2. Location of the case study areas along the German-Czech border (Ore Mountains / Erzgebirge / Krušné hory), the Ukrainian Carpathians, boreal and hemiboreal forest in NW Russia, and Sweden. The forest cover themes in the background illustrate the long gradient in forest landscape histories between the SE and NW parts of the European continent.

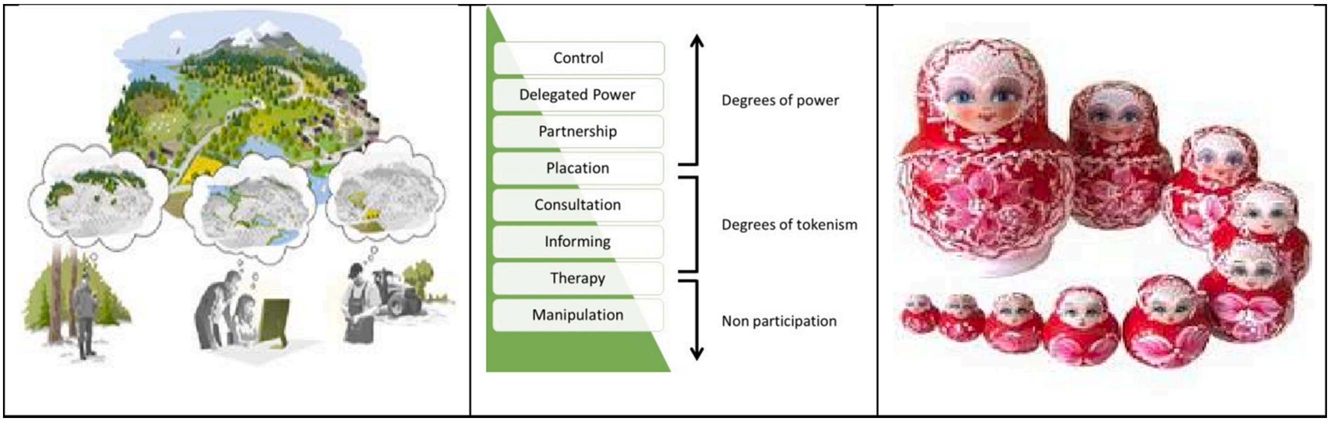

Fig. 3. Forest landscapes are complex social-ecological systems. Regarding the biosphere we focus on the multiple benefits provided by natural and cultural forest biodiversity (species, habitats, processes) (left). For society we focus on stakeholder interactions and their degree of power (centre), and for economy the hierarchy of steps embedded in value chains (like a matryoshka doll (Russian: Матрёшка)) (right) (Sources: https://www.naturvardsverket.se/upload/stod-i-miljoarbetet/vagledning/gron-infrastruktur/bild/prioritera-planera-stor.jpg, Arnstein, 1969; Merlo and Croitoru, 2005), photo.

landscape where maximum sustained yield wood production is the focus.

(2) Societal stakeholder interactions and power.

Any social-ecological system involves actors and stakeholders at multiple levels (Arnstein, 1969; Fig. 3 centre). Stakeholder structures are generally complex and dynamic, and thus provide different vantage points for analyses, the choices of which are likely to affect conclusions. We identify a suite of actor and stakeholder groups across different levels ranging from local forest owners to global level investors. For each we discuss interactions and power dynamic over time.

(3) Economic accounting and multiple currencies.

Economic geography is the study of interactions between economic agents in value chains in space and time (Fig. 3 right illustrating nested economic levels). The term narrative economics, that popular stories can affect individual and collective economic behaviour (Shiller, 2019), is a new emerging phenomenon. This calls for the strong need "*to enable citizens to reclaim possession of economic and historical knowledge*" (Piketty, 2020:1041). Examples of relevant questions are the following. Who makes money on what? Are there hidden direct and indirect costs? What are the roles of foresters vs. that of markets and investors? How are citizens' willingness to pay for landscape services evolving?

3. Results

3.1. Development of even-aged silviculture as a replicated transition

Forest patterns and processes provide multiple material resources and immaterial benefits. Transforming naturally dynamic forest landscapes through management for wood production, and deforestation for agriculture, are long-term processes (Angelstam et al. 2021a). Different phases are replicated globally (e.g., Thomas, 1956). Williams (2003:146) highlighted two "theatres of action" based on the connection between demand and supply, linked to flow of wood using seas and other waterways to centres of economic development, and later by expanding frontiers of forest use and value-added production. Focusing on four European regions we summarise the emergence of even-aged silviculture, which confirms this pattern (see Appendix abbreviated in Table 2)

3.2. Three groups of vantage points

3.2.1. Biosphere's composition, structure and function across scales

Biodiversity is about composition (species), structures (habitats) and function (processes) of ecosystems (e.g., Noss, 1990; Brumelis et al., 2011). One can formulate at least four different levels of ambition for the conservation of biodiversity (Angelstam et al., 2004) (Fig. 4 left). A first level is occupancy of individuals of species in a remnant patch of a once widespread habitat. However, this is an insufficient criterion for

Table 2
Overview of four social-ecological contexts illustrating the gradual adoption during ca. 300 years of even-aged silviculture in central, eastern and northern Europe.

Case study area	Initial driver	Policy and training, and level of adoption	Current ecological system context	Current social system context
Ore Mountains	Mining and metallurgy	Saxony 1713; effective adoption and application during > 250 years	Mainly spruce monocultures hit by air pollution, climate change and bark beetles	Societal preferences favour closer-to-nature forest management; growing insight that impacts of more frequent heat and drought events undermine the viability of even-aged silviculture
Carpathians Mountains	Mining and metallurgy, potash for glass production	Theresian Forest Code 1769; adoption and application during > 200 years	Monocultures hit by climate change and bark beetles, deforestation	Rural livelihoods depend on forest landscapes, illegal logging; rapidly progressing loss of spruce monocultures
NW Russia	Mining and metallurgy, fuel wood	Tsarskoe Selo Forestry Institute 1803; local adoption by tsar and nobility, abandoned during communism, now attempted	Wood mining of primary forests dominates	Rural livelihoods depend on forest landscapes
Sweden	Mining and metallurgy	Royal Academy of Forestry and Agriculture 1813, Forest institute 1828; regional adoption from the 19th century, and nationally from the mid-20th century	Rivalry between increased wood yields desired by forest industry, and biodiversity conservation	Decline of rural forest jobs due to mechanisation, rationalisation, and foreign guest workers. Societal preferences favouring closer-to-nature forest management

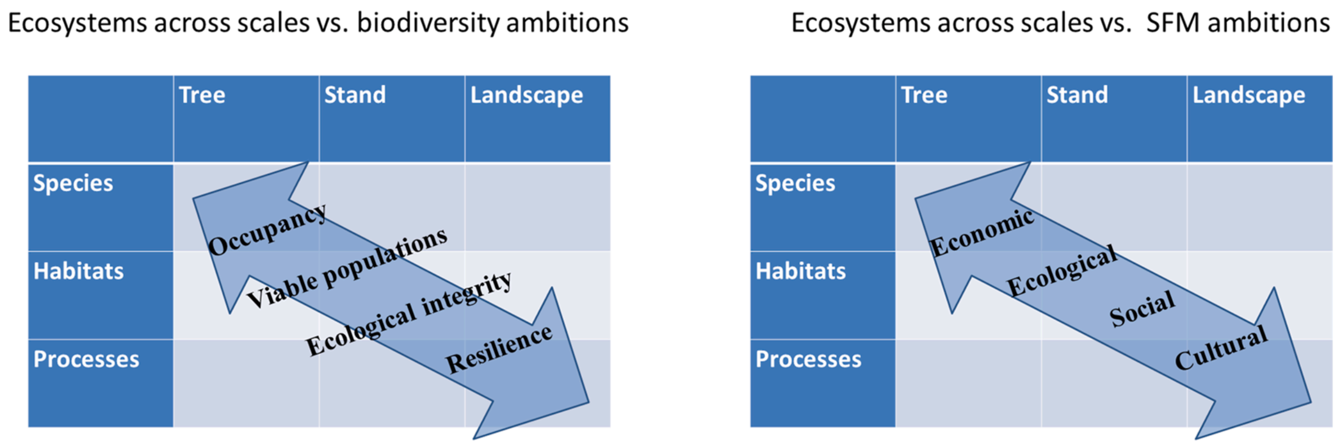

Fig. 4. Illustration of how components of ecosystems (rows) across spatial scales (columns) relate to levels of ambition for biodiversity conservation (left), and dimensions of sustainable forest management (right).

successful conservation of naturally occurring species in viable populations over long time, which thus forms a second level of ambition. Because ecosystems are dynamic, the total area extent of minimum dynamic areas needed to ensure the persistence of species in viable populations is higher in the long term than in the short term (Pickett and Thompson, 1978). Consequently, a third level of ambition is to ensure ecosystem integrity and health (e.g., Pimentel et al., 2000) allowing interactions among species and processes (e.g., Bengtsson et al., 2003). Finally, a fourth level of ambition is to ensure ecological resilience (Gunderson, 2000), for example under scenarios of climate and global economic change. The latter levels of ambition are included in more holistic concepts that try to capture the key ecological attributes that describe the conditions required for existence and functioning of ecosystems and their components (Schick et al., 2019). These different levels of ambition apply both to visions of natural forests and cultural woodlands (Angelstam et al., 2021a).

Satisfying economic, ecological, social and cultural dimensions, respectively, of sustainable forest management requires increasing spatial extents and time horizons (Fig. 4 right). The stand scale in forest management units is the focal scale for current intensive production forestry aimed at producing industrial raw material that flows into economic value chains maximising economic gains. On the contrary, the landscape scale is the focal scale for higher levels of ambition for biodiversity conservation, and for most of the other components of sustainable forest management. Conservation of habitat for species that cannot cope with even-aged monocultural stands is attempted through leaving behind of retention trees, tree groups and small patches ('biodiversity pockets'). However, compared to relevant evidence-based performance targets, the amount of retention structures being set aside is low (Kuuluvainen et al., 2019; SLU, 2020:33; Angelstam and Manton, 2021), the longevity is short (Rosenvald et al., 2019), tree species composition is simplified (Lodin et al., 2017), and there are limited efforts towards spatial planning (Curtis, 2020). Alternatives to the dominating (>95%) even-aged forest management system in Sweden include continuous cover (e.g., Puettmann et al., 2009), and disturbance-based forest management approaches (Kuuluvainen et al., 2021) (Fig. 5). The gradual transformation to effective sustained yield even-aged forest management can be described as successive frontier of expansion (e.g., Angelstam and Manton, 2021), which has left only inaccessble locations with remnants of near-natural forests. This means that formally protected areas are unevenly distributed among different ecoregions, and that representive functional habitat networks (e.g., green infrastructures) have limited funcionality (Angelstam et al., 2020).

Sténs et al. (2019) elegantly showed that while it is easy to get

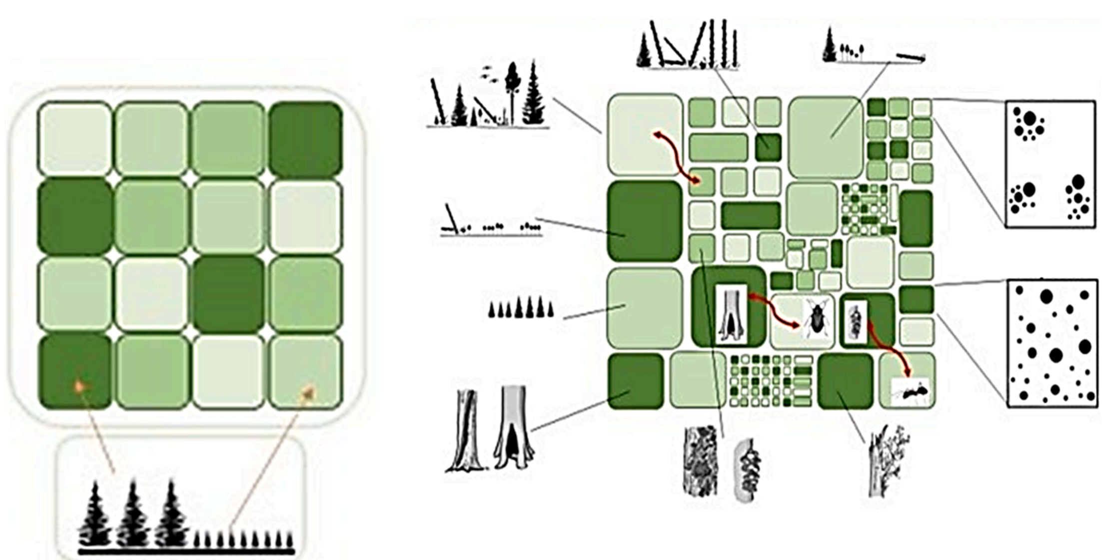

Fig. 5. Illustration of the composition and spatial configuration of different components in managed forests (stand age classes) and in naturally dynamic forests with connectivity, complexity, heterogeneity of aggregated and dispersed habitats (illustration by Miroslav Svoboda).

acceptance in industrial forestry for a modification of even-aged management like tree retention, it is difficult to add a new forest management system like continuous cover forestry. Introducing close-to-nature forest management based on natural disturbance dynamics (Kuuluvainen et al., 2021) is even more challenging. Social values are attached to forest management units with multiple stands, and differ considerably among forest owner categories such as forest industry, non-industrial private, and collective forest commons, municipal and other public owners. Finally, there may be cultural differences among different landscapes, regions and states, as well as forest owners who own forest for different reasons, viz. to produce wood, to honour cultural or natural legacies, and as a real estate investment. Inspired by Puettman et al. (2009:90), Table 3 illustrates the types of difference in values that different stakeholder groups see.

3.2.2. *Forest management actors' levels of participation and power*

Expectations of what landscapes should provide vary in time and space, and among stakeholder groups with different desires, perspectives and value systems. This stresses the importance of understanding the role and meaning of policy trajectories arguing for sustainability of different sorts and levels of ambition. Tracking the traditional industrial forest value chain from local forest owners to global level investors we chose six levels; viz. (1) non-industrial forest owners, private industry and timber buyers (Curtis, 2020) who engage, (2) forest workers and machine operators (Ager, 2012) belonging to, (3) organisations and industry buying wood for production of value-added products, led by (4) professionals with guild values based on the national forestry education system (Lawrence, 2009, Lisberg Jensen, 2010), and (5) dynamics of policy national level policy instruments representing "carrot, stick, or sermon" (Vedung, 1998), as well as (6) national, EU and international levels represented by policy developments driven by public choice at national, EU and Pan-European levels, and by evolving values on the market and among investors (World Economic Forum, 2021).

Table 3
Impact of different "lenses" for viewing naturally dynamic and managed boreal forests.

A boreal forest landscape subject to natural disturbance regimes	Boreal landscape with maximum sustained yield even-aged management for 60–100 years
View of traditional silviculturists	
Depending on site, even-aged, multi-cohort, and uneven-aged following an inverse J curve	Even-aged and monocultural that can be adapted into current traditional planning and management for wood production
Young vigorous to over-mature and decadent forest	Productive regular rotation forest subject to cycle of felling-planning-cleaning-thinning
Basal areas range from 0-45 m^2	
High standing volume due to old stands	
Lots of dead and diseased trees	Basal areas of 0–32 m^2
Commercial biomass production is reduced	Effective production of wood
	Vigorous and straight trees
Variation in tree species mixtures	Biomass production is maximised
With 2 coniferous and 5 deciduous species	One or two species
	With 1–2 conifers
A messy forest with gaps, crop and non-crop species, dense understorey, diseases	A productive uniform forest with distinct and homogenous stands
	A productive forest that plays to its full potential in terms of timber harvesting
A forest that needs to be managed to be productive	Visually orderly forest
Unattractive, uninviting and needs be managed to become attractive	
View of ecologists	
A mixture of development stages and disturbance types	A younger man-made forest
A diversity of structures and processes at multiple scales	A simplified forest with simplified structure, low diversity, and low harvestable biomass
Very large live and dead trees	
Very rich forest in term of species	Lack of large and diseased trees as well as deadwood
High level of vertical and horizontal heterogeneity and complexity	Few species
Once of the normal conditions of this region	Low level of vertical and horizontal heterogeneity
A forest that needs disturbances to be maintained	Today very rarely found in the region
	A forest to restore by introducing disturbances
Functional and diverse habitat for animal life in terms of nutrition and shelter	Poor shelter and habitat
	Monotone
Visually appealing with many life forms	

(1) Non-industrial forest owners and timber buyers

The regional distribution of different forest owner categories in Sweden is diverse. It mirrors the gradual human appropriation over Millenia of forest landscapes for production of food, feed, fuel and fibre, which spread from south to north to landscapes with diminishing productivity at higher latitudes and altitudes (e.g., Angelstam et al., 2020). Thus, in the far south around 80% of forests have small-scale non-industrial private owners, also traditionally having agricultural land until recently sustaining rural small farmsteads, while in the north this proportion is 30%. Conversely, public and state-owned forests are concentrated to the north and higher altitudes. The average proportion of non-industrial private forest (NIPF) land ownership in Sweden is 49%, which supplies about 62% of the annual fellings used by the forest industry (SLU, 2020). This means that timber buyers, who are employed mainly by forest industry companies, wood procurers and forest owner associations, have a key role as the first link in the traditional industry-based value chain (Curtis, 2020). Timber buyers and forest inspectors of forest owner associations are also the primary actors providing advice about forest management to NIPF owners. These advisors focus on maximising mobilisation of roundwood by advocating the even-aged forest management system (Elbakidze et al., 2013; Felton et al., 2020; Jakobsson et al., 2021). NIPF forestry thus builds upon interactions at the local forest property level. Based on interviews with forest owners, managers and other forestry stakeholders, Guillén et al. (2015) explored the role of trust towards two major actors in south Swedish forestry. These were Swedish Forest Agency (SFA) staff and the forest owner association and industry named Södra (southern in English). A local client-based focus, and personal features of SFA staff, led to high trust towards the SFA. However, SFAs advisory capacity is declining due to staff reduction and <5% of clear-cut notifications involve consultation. On the other hand, industrial priorities of Södra seemed to erode forest owners' trust. Thus, with the strong focus on wood production, in spite of spatial competence, data access and technical skills (Curtis, 2020), the potential of wood buyers to support the necessary landscape perspective towards multifunctionality is not realised. The absence of such training in the Swedish forest education programmes providing the supply of wood buyers reinforces this.

(2) Forest workers and machine operators

For long time forestry aimed at wood production provided abundant rural jobs. Ager (2012) reviewed the change of forest work in industrial forestry in Sweden 1900–2011. The focus was on rationalization and humanization processes. More than a century ago, alarming conditions and health situation were observed among forest workers. A humanization period was initiated and resulted in improved housing for forest worker teams as well as employment of cooking personnel. Industrial forestry started a systematic rationalization of forest work, including mechanization combined with work studies from the 1950s, and organizational development from the 1970s. During the intense mechanization period, the human being in the system was neglected until increase of accidents and diseases triggered reactions. Humanization again increased and led to a culmination of human qualities around 1990. However, a major national economic crisis in the early 1990s led to high unemployment in forestry, and humanization actors were weakened or vanished. Subsequently, adopting "Lean Production" in management, and thus laying off employees and instead outsourcing operative resources to contractors, and 97% seasonal foreign workers

(Forsmark and Johannesson, 2020), productivity was improved and costs controlled. After that productivity stagnated. After 2000 forest shift work has become less attractive, causing recruitment problems and limited profitability for industrial forestry entrepreneurs involved with wood harvesting.

(3) Organisations and industry buying wood for production of value-added products

Spatial concentration of value-adding industry units, leading to death of inland sawmills and bigger units with more effective production with less staff at coastal locations, have been effective means of reducing production costs. In spite of this, according to Statistics Sweden (scb.se) contributions to Swedish GDP from forestry aimed at wood production and forest industry has declined from ca. 12% in the early 1950s to 3.6% 1993 and 2.2% today. Employment in forestry was thus for long time a core source of jobs, and a demography that made municipalities thrive in terms of a high proportion of tax paying inhabitants as well as a not yet ageing population requiring care and medical service. However, this has changed dramatically with both mechanisation, and foreign guest workers doing tree planting and pre-commercial thinning.

Increasing forestry intensity has additional drivers. Associations of forest owners have changed side on the wood market, from non-industrial forest owners to wood buyers with industry possesions. Currently, the available unprotected Swedish wood resource is utilised by the forest industry, or lost due to natural disturbances, to ca. 97% (Fig. 6). Thus, options for increased harvesting are limited. Industrial roundwood demands exceed domestic felling by 10%, which is covered by importing 7 million m^3 to maintain industrial production (Nordström et al., 2021). Imports from Norway may be an attractive way to maintain and expand industries in western Sweden. In Finland pulp capacity is expected to increase with 1–2 new mills, partly based on increased imports from northern Sweden. At the same time paper mills are being closed due to digitisation and new consumption patterns. With increased demand in both Sweden and Finland, competition for export volumes from the Baltic countries will increase further.

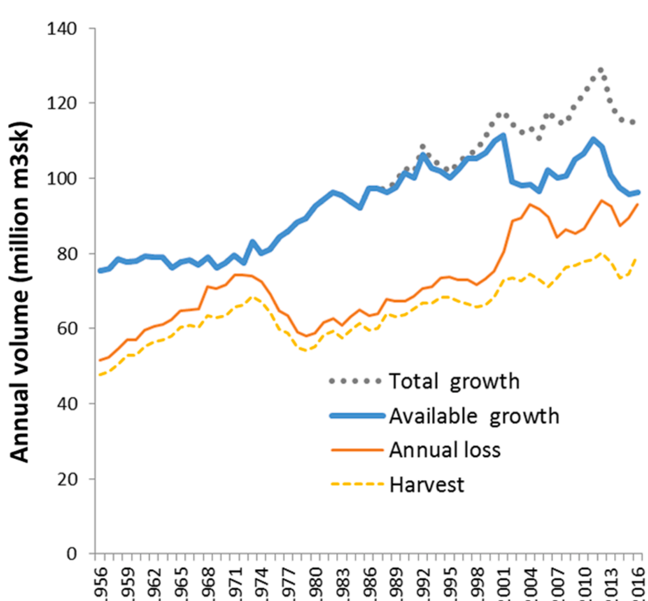

Fig. 6. Due to increased set-asides to satisfy environmental objectives, increased annual losses due to storms and bark beetles during the recent three decades, and increased felling volumes, almost all (97%) of the available growth volume produced in Sweden is currently harvested (data from SLU 2020:49). More recent data points will be available in 2022 (J. Fridman, SLU, pers. comm.).

(4) Professional guild values based on the national forestry education system

Forestry science originated in central Europe, and training took place at forestry schools in Germany and France, and was later propagated globally. For long time, expertise of foresters practising even-aged forestry was relatively uncontested. From the 1970s an increased interest in outdoor recreation (Jordbruksdepartementet, 1974), and in particular conservation of habitats and species began to question even-aged forestry. At present also economic and social changes are currently challenging even-aged forestry (Puettmann et al., 2009; European Commission, 2021). The fact the forest management systems are tied into histories of power, institutional cultures, product portfolios and political rationalisation (e.g., Lawrence, 2009), explains the difficulty to acknowledge the need for multiple approaches towards multifunctional forest landscape management (e.g., Kuuluvainen et al., 2021). Foresters acquire expertise, trough legislation and education, and through their own authority based on emotional commitment to the forest goods. Lisberg Jensen (2010:138 ff.) used the anthropologist Victor Turner's (1967) studies of initiation rites as a framework to analyse the forestry education as a "*powerful socialisation process where teachers and students collaborated in developing and maintaining a collective culture*". This created professional and private cohesion among participation of individual courses supported by songs, clothes, mascots and shared memories, as well as a selfconfident group identity regarding what forests are for. Such professional guild patterns can contribute to the exclusion of marginal stakeholders including reindeer herding Saami people, nature-based tourism and environmental NGOs (Sténs and Mårald, 2020; Fischer et al., 2020), and to domination of an industry perspective in forestry education and research (Westholm et al., 2015; Andersson and Westholm, 2018). The Swedish forest education programmes are, however, being diversified from the academic year 2021/22 by having forest practice, natural science and social science as entry requirements, and BSc and MSc programmes focusing on forestry, biology, landscape architecture, and economy. Interestingly, while the three BSc and MSc programmes in forestry had 1.1 first hand applicants per study place in 2021, the new landscape-oriented forest management programme had 1.9 applicants (O. Lindroos, pers. comm.)

(5) Dynamics of policy instruments representing "carrot, stick, or sermon"

In parallell to the long delivery time for creation and restoration of ecological dimensions such as old trees, stands with several tree generations and decayed dead wood, a long-term perspective on different phases of forest use through multiple forest policy cycles is appropriate.

Phase 1.0 (Medieval to 19th century) involves the traditional village system (Elbakidze and Angelstam, 2007), which maintained livelihoods based on multiple use of forest landscapes (Myrdal and Morell, 2011). Villages were organised by a "garden-field-meadow-pasture-forest" zoning, and with strong collaborative traditions (Angelstam et al., 2021b).

Phase 2.0: (ca. 1830–1970s) Gradual development, acceptance and dissemination of even-aged forest management maximum sustained yield of industrial raw material in three steps (e.g., Holmberg, 2005) (**Phase 2.1**). Clear-felling systems aiming at maximum sustained yield of wood for charcoal emerged regionally in mining and metallurgic core region Bergslagen in the 1840s. (**Phase 2.2**). North Sweden is reached by successive frontiers of "wood mining" along river valleys (Angelstam and Manton, 2021), and a rapidly increasing export of wood products. After long discussions beginning 1853, through the Forest Committe (1855) and creation of the Swedish Forest Agency, to 1896 about tools and instruments, the 1903 forest policy took the first national level steps to sustaining wood production. (**Phase 2.3**). State subsidies and advice to increase wood production and industrial value was taken in several steps, and led to the 1947 policy supporting the forest industry that encouraged rural development, based on even-aged rotation forestry (Jordbruksdepartementet, 1974).

Phase 3.0: (1970s to late 2010s) The first reaction against the widespread clear-felling system with a focus on nature conservation emerged in the mid-1970s, and shaped the 1993 forest policy by introducing productive and environmental objectives under the slogan "freedom and responsibility" (Beland Lindhahl et al., 2017): "*A long-term use of the forest must take place in accordance with the natural conditions. The forest owner has a responsibility to, as a starting point, seek to benefit or at least maintain the biological diversity when the forest is used.*" (SOU, 1992:76, p 14). However, hopes for success in the balancing act between production and environment, have not been achieved due to forestry intensification (Felton et al., 2020), which in the north has resulted in a net loss of high conservation forests (Svensson et al., 2019), and a deteriorating green infrastructure functionality (Angelstam and Manton, 2021).

(6) National, EU and international levels of governance

Scenarios of climate change and forestry intensification have triggered the emergence of the three new concepts circular economy, green economy and bioeconomy (Birner, 2018). They are currently mainstreamed as key sustainability avenues with relevance for how forests are expected to be managed. D'Amato et al. (2017) compared these concepts, and concluded that green economy acts as an 'umbrella' concept for all three, and which encompasses circular economy, and bioeconomy elements such as eco-efficiency and renewables, and nature-based solutions. However, the first two are more resource-focused, whereas green economy acknowledges ecological processes as a foundation. Regarding the social dimension, green economy includes also eco-tourism and education, while the bioeconomy literature discusses also biosecurity and rural policies. Despite this, there seems to be little consensus concerning what bioeconomy actually implies. Bugge et al. (2016) made a bibliometric analysis showing that bioeconomy research is distributed across many disciplines. Three visions of bioeconomy were identified, viz. (1) bio-technological commercialisation, (2) a bio-resource vision focusing on establishing of new value chains, and (3) a bio-ecology vision focusing on sustainability by optimising the use of energy and nutrients in ecosystems, promoting biodiversity, and avoiding monocultures. Integrating these alternatives could form a phase 4.0 in which forests are seen not only as cropping systems, by as complex adaptive social-ecological systems (Messier et al. 2015). By addressing the social, economic and environmental aspects all together, the recently released, and contested, EU Forest Strategy (European Commission, 2021) aims at ensuring the multifunctionality of EU forests in a way that preserves the vital ecosystem services that forests provide and on which society depends. This strategy sets a vision and concrete actions for increasing the quantity and quality of EU's forests, and strengthening their protection, restoration and resilience. The European Climate Law (Anonymous, 2021) aims at making the EU climate-neutral by 2050, and after that with negative emissions. The intermediate target is to reduce net greenhouse gas emissions at least with 55% by 2030, compared to 1990 levels. Proposed actions aim at cutting emissions, green technologies, increasing carbon sequestration through enhanced sinks and stocks, to strictly protecting primary and old-growth forests, and restoring degraded forests. However, the EU forest strategy is seen by some Member State governments and the wood-based forest sector as an intervention on national sovereignty. On the other hand, actors advocating multifunctional forest welcome the opportunity to improve forest protection and diversify forest management in Member States.

3.2.3. Economic value chain hierarchies and currencies

Historically, the value of forests have been related to the yield of material benefits, from pastures for domestic animals, game species for food and sport, wood and biomass. This contrasts what could be termed "fairy tale accounting" as a new main driver of profits in the Swedish forest industry. Increasing book values of the forest land holdings per se has taken over as the main profit driver in the Swedish forest industry and the forest property sector. It can be argued that this conceals the low profitability of the industrial processing parts of the wood-based value chain. The Swedish forest industry is facing tough structural changes, and increasing competition for wood (Nordström et al., 2021). The main force has been the digitalization of media, which has eroded the demand for newsprint and journal graphic paper (Robert et al., 2020). This segment has historically been one of the most profitable parts of the forest industry. Three factors contributing to high productivity and low unit costs were (1) cheap electricity thanks to state support for the thermomechanical industry process, (2) good sourcing of wood at reasonable to low prices for the other main input, (3) and that Swedish mills being positioned at the technlogical frontline.

However, during recent decades the Swedish forest industry has closed more than half of the newprint and journal paper machines. The profitability of the Swedish and Nordic pulp and paper companies has also been impaired by a number of unsuccessful acquistions and mergers. The ambitions have been to follow the examples from other industries to consolidate the owner structure in the business and thereby increase the pricing power and profitability. This has not materialized. The packaging paper segment has, however, not been exposed to the same problems. Actually this is the most popular "growth story" in the industry today. Increasing e-commerce is the selling point. The real development has, however, been mixed. The demand has in practice more or less followed the general economic GDP development. Formerly profitable, and in some cases very profitable, niches like liquid carton (Tetra Pak being the main customer), solid bleached board, folding box board have seen a gradual decline in profitability. The more "bulk" oriented packaging products like kraft paper as well as liner and fluting (for making corrugated boxboard) have had a lower profitability, and on average just about reached its cost of capital. The producers lack pricing power. These product areas have been more volatile, more depenent on the business cycle and the relative value of the Swedish currency (SEK), as most of the production is exported. Last but not least the competition for packaging paper comes from plastic.

During the 1990s and early 2000s pulp production was mostly seen as an intermediate product exposed to volatile pricing and the USD/SEK exchange rate. The continuously weak Swedish currency since the global economic crises 2008–09 made the Swedish pulp production decently profitable. The other more basic branches of the forest industry, saw milling and wood products processing, has historically had a subordinated role among the largest players in the Swedish forest industry. The profitability in the sector mirrors the volatility of the pulp business, with a distinguishing pattern that the smaller focused saw mill companies have had a clearly higher profitability than the corresponding parts of the larger integrated companies. The saw mill business have had a more tactical role to control the flow and the price of wood fibre for its more important pulp and paper business. However, for NIPF owners valuable saw timber is an important economic driver. Hence, there is dichotomy in what drives forest managment and harvesting between NIPFs and industrial forest owners.

To summarize, from a similar level in 1981, while the tech industry has grown five-fold to 2019, the Swedish pulp, paper and wood product business has been on a slope of decline during the same period (IT&Telekomföretagen, 2021). That environmental aspects and global ambitions aiming at phasing out fossil-based products and reduce the CO_2 footprint is well advertised and embraced by the industry. The critical issue is to make a truly economically profitable expanding business out of these ambitions. Another challenge is that the forest industry's own environmental impact, when it comes to its CO_2 footprint (Rummukainen, 2021), biodiversity conservation (e.g., Felton et al., 2020) and climate mitigation efforts (Camia et al., 2021; Grassi et al., 2021) are increasingly questioned.

A new economic driver is the decline of the real rate of interest, and with that the decline of return on financial assets. During the last decade there has been a "hunt for yield" in the financial sector. Assets producing a stable return or yield have seen a very strong appreciation. The asset in the large pulp and paper companies that is considered to have this characteristic is forest land itself. A major change of the perception of the asset forest land followed the change in the accounting rules for public companies in 2003, when IASB (International Accounting Standards Board) introduced the accounting rule IAS 41 for biological assets in the group account of public companies. IAS 41 requires the group accounts to reflect fair value in the accounting of biological assets. The reported value of standing timber should be a reflection of the fair value of the timber, less estimated point-of-sale costs. The previous accounting standard was based on the historic costs, which for the Swedish forest owning companies were low. This had a large impact on the profit and loss (P&L) account and the balance sheet of these companies. The continuous net change of market value of the growing standing value of timber was introduced in the P&L and the change from historic aquisition cost to fair value increased the value of the standing timber in the balance sheet and had a large one-time-effect in the P&L. The value of the timber was calculated using the discounted cash flow model.

As the Swedish forest owning companies have a large part of rather young standing timber, after the extensive fellings in the 1970s and 1980s (e.g., Angelstam and Manton, 2021), and consequently a large net growth, i.e. total growth minus fellings, in the volume of standing timber, this have had a growing negative impact on the accounted incomes and profits. The new rule of the fair value of forest land increased the reported profits, and smoothed out the results over the years. This thus consealed that the actual earnings and cash flow from the fellings were both volatile and decreasing, as can be seen in the financial reports from Bergvik Skog 2005–18 and Sveaskog 2000–2020. However, the IAS 41 accounting rule made a distinction between the valuation of the standing timber and the value of the actual land. The latter was valued at the historic cost. In 2013 IASB took a further step in the fair value acquing direction with the introduction of the IFRS 13 in the group accounts. This required public forest industry companies to account for the market value of all its assets and liabilites. The market value was defined as "*the transaction price of an asset or the payment to transfer a liability in an ordered transaction between two market participants at the time of measure*".

As there were few transactions in larger forest land holdings, companies have some freedom in chosing between the dicounted cash flow method, and a valuation based on comparisons to actual market transactions. But the realized prices in the private market of forest land has steadily increased, measured as the price in SEK per standing m^3 of timber, during the past >20 years (Fig. 7). The forest owning companies have therefore adopted a valuation based on market transactions in "comparable areas". From the accounts of 2020 they have taken a full step to market value based accounting.

This has had a remarkable effect on their P&L and balance sheet accounts. SCA reported an operating profit of 1.145 billion SEK for 2020. But the contribution from "revaluation of biological assets" contributed 1,242 billion SEK. The pulp, packaging and saw mills, as a whole, were loss making. From an industrial and financial perspective this is remarkable. If the processing part of the forest industry is not returning its cost of capital, and are even lossmaking, because lumber is the totally dominant income stream of the asset, are the values of the biological assets and the forest land sustainable? Is"fair value accounting" more like "fairy tale accounting", thus hiding the real problems of limited wood resources and new products and services demands in the forest industry sector (e.g., Nordström et al., 2021)? The role of corporate businesses to induce change has nevertheless potential to support the development of multifunctional forest landscapes by considering Environmental, Social and Governance (ESG) dimensions (cf. Friede et al., 2015). Folke et al. (2019) reviewed evidence of current practices and identified a suite of features of change towards 'corporate biosphere stewardship'.

4. Discussion

4.1. Synthesis of cultural values and their dynamics

4.1.1. Comparisons of social-ecological systems

The summary of the four case study regions in central, eatern and northern Europe illustrate the persistent and successful dissemination of the culture of even-aged silviculture during more than two centuries. The even-aged forest management regime provides sustained wood yields for the forest industry, and has led to a widespread acceptance of this approach in both Old and New World boreal regions (Burton et al., 2003) and elsewhere. However, limited or no attention was for long paid to alternative viewpoints and management methods supporting also biodiversity conservation, rural development, recreation and nature-based tourism, human quality of life, and carbon storage (Puettmann et al., 2009; Kuuluvainen et al., 2021). This has resulted in a "lock-in" of experts to their traditional approaches and paradigms of thinking and working (Puettmann et al., 2009; Moen et al., 2014). Currently, the notion of multifunctional forest landscapes is challenging this (European

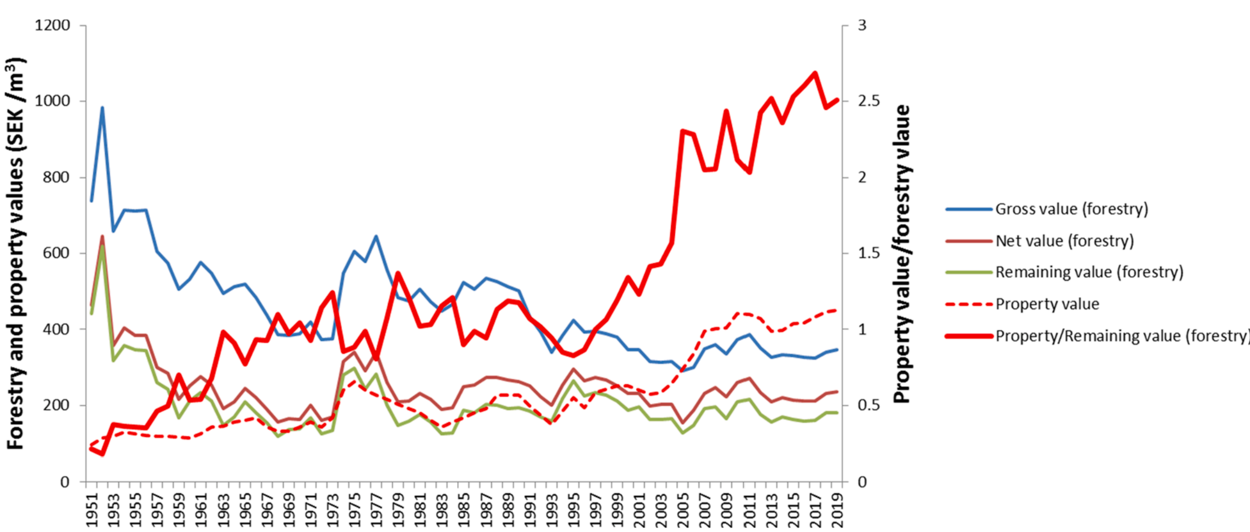

Fig. 7. Temporal dynamics of forestry values (m3f pb, Swedish Forest Agency, official statistics) and property values (Martin Persson, Ludvig & Co, pers. comm.; Thor, 2012) in prices (10 SEK is ca. 1 €) of 2019 (m3 sk), and on the right-hand axis the ratio of property values to remaining forestry value after harvesting and regeneration costs.

Commission, 2021). The combined effects of national and international public choice, business interests, and climate change, form a portfolio of new strong drivers supporting a transition. Effective responses will, however, require fundamental structural changes in the traditional forest-based sector, particularly aiming at increased social and ecological resilience. Altogether, this indicates that radical changes in forest landscape management are required (Hlásny et al., 2021). This includes multiple forest landscape management approaches involving both even aged and un-even aged approaches, emulation of natural and cultural disturbance regimes, mixtures of different tree species, prolonged forest rotations, landscape planning towards functional and representative green infrastucture, and landscape restoration (e.g., Kuuluvainen et al., 2021).

Social system drivers include both human welfare and well-being. European countries differ much in the number of jobs in primary and secondary steps of the wood-based value chain (Robert et al., 2020). This indicates that intensified production of industrial raw material is not as effective compared to focusing on innovations that increase the economic value of wood-based products. This is particularly important because competitors in the global south have cheaper raw material, and thus have better profits (Rennel, 2011). This forms a threat to employment, which calls for encouraging value chains based on both wood and non-wood goods, as well as natural forests and cultural woodlands (Jonsson et al., 2019). Rural exodus driven by mechanisation and larger more cost-effective industrial processes is associated to increased urbanisation. Public concerns about human footprints on forest ecosystems, and recently the increased public use of protected areas and green spaces, increases the number and diversity of green infrastructure beneficiaries encompassing both rural and urban citizens. Additionally, there are examples of increased use of green infrastructure to cope with the stress of the COVID-19 pandemic and to perform outdoor activities with social distancing (Heo et al., 2020).

4.1.2. Learning from multiple vantage points

Using the Swedish forest landscape history, through the lenses of the biosphere, society and economy, we illustrate that there are multiple perspectives on natural forests and cultural woodlands. The collaborative transdisciplinary research journey behind this study has provided valuable insights into the diversity of social-ecological legacies, which have created a particularly strong culture of forest management in Sweden aimed at effectively producing industrial raw material.

This is in stark contrast to policy about sustainable forest management (Forest Europe, 2015) and green infrastructure supporting biodiversity conservation and human well-being (European Commission, 2020). Given barriers among what stakeholder groups claim that forests and woodlands should deliver, among sectors as isolated societal silos, and among multiple levels of governance, the presence of a currently heated debate between advocates of business as usual and reform is not surprising. Our conclusion is that transforming a system with cultural legacies of this magnitude require either severe outside international regulative or market-based pressures, or very strong incentives for change from the inside mediated from below through pressures from a range of societal stakeholders in favour of multifunctional forest landscapes, including the diverse group of non-industrial forest owners. The latter would require that forest stewards and managers would become ecosystem managers and not merely biomass managers.

Three appearing public choice drivers towards a diversity of ecosystem and landscape services (Elsasser et al., 2021) provided by functional green infrastructures are: (i) the need for adaptation linked to climate change, (ii) international corporations' increased focus on the opportunities and avoiding risks, and (iii) biodiversity conservation challenges. Transnational corporations in agriculture, forestry, seafood, cement, minerals and fossil energy do cause environmental impacts. The World Economic Forum (2021) has identified biodiversity loss as the fourth-greatest global risk, after infectious disease, climate action failure, and weapons of mass destruction. However, if combined with effective public policies and improved governmental regulations, transnational corporations could substantially accelerate sustainability efforts. According to the European Investment Bank's vice president, investments in climate adaptation and mitigation may be the required, and also green investments can attract money (Kurth et al., 2021). To conclude, the multiple vantage point approach demonstrates that the breadth and width of topics to consider around forest landscapes requires a holistic multi-dimensional and multi-level systems perspective.

4.2. Towards a suite of deep leverage points

4.2.1. Incremental vs. Transformative change

Promotion of multifunctional landscapes requires development of holistic management strategies, which can consider both synergies and trade-offs (Moen et al., 2014). Felton et al. (2020: Table 2) listed a suite of three categories of leverage points (*sensu* Meadows, 2008) ranging from deeper to shallower, thus supporting the diversification of forest management practices. First, as examples of the category intent, including stewardship that balances societal interests, avoiding negative biodiversity outcomes, linking bioeconomy to multiple ecosystem and landscapes services, and integrate green infrastructure and a diversity of forest management systems. Next, landscape governance and design levers need to be matched by regulation, spatial planning, integrated management, extension service, education, third party certification, active adaptive management and monitoring. Finally, practices as levers should prioritise areas with high natural or cultural conservation values, encourage collaboration among land owners, rely on natural regeneration, monitoring of indicators representing different ecosystem and landscapes services. However, as Dasgupta (2021) stressed, such levers represent incremental and peripheral (Fig. 8) rather than transformative changes that are likely to affect long lasting culture of even-aged forest management.

Our tentative review using three different vantage points in landscapes as social-ecological systems extends this seemingly comprehensive list of levers that would promote multifunctional forest landscapes. The summary of forest management trajectories in the Central European Ore Mountains (Germany and the Czech Republic), the Ukrainian Carpathians, NW Russia and Sweden confirms this. Both these analytic approaches demonstrate that cultures of practising particular forest management approaches can be both an assett and a burden in terms of providing levers that can, or cannot, trigger transformative change for the evolution of forest management cultures better adapted for developing and maintaining multifunctional forest landscapes. Stemming from our observations from the vantage points of biosphere, society and economy, and the different case studies, below we list seven topics forming deeper levers, which if addressed, have potential to support transformative change (Fig. 8).

4.2.2. Valuation of and payment for ecosystem services

Multifunctional landscapes encompass a wide range of desired aspects, for some of which incentives to maintain them are limited or lacking. Depending on motivations for incentives focusing on the biosphere itself, society or economy, this may include pre-commercial cleaning in young forests, nature conservation management, surveys of natural and cultural heritage values, provision of access to land for outdoor recreation and trails, restoration of watercourses and riparian zones, measures for climate adaptation and carbon storage for climate mitigation. Payment for ecosystem services is thus a kind of policy instrument (Vedung, 1998). For example, Assmuth and Tahvonen (2018) noted that a transition to carbon pricing causes a switch from even-aged to continuous cover management rather than vice versa. Societal investments can also be evaluated. Elsasser et al. (2021) tried to estimate the monetary value of forest landscape benefits in terms of timber production, carbon sequestration, local residents' recreation, nature protection and landscape amenity across Local Administrative Units (municipalities) and NUTS-3 level units (regions) in Germany.

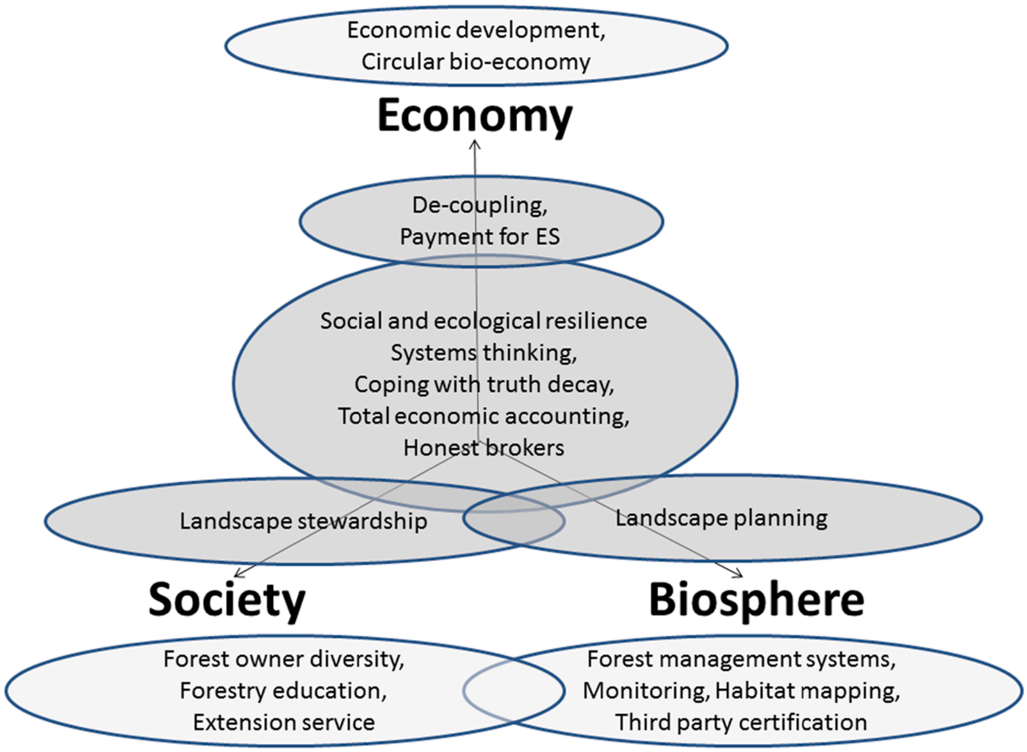

Fig. 8. Illustration of three vantage points representing the biosphere, society and economy, and a suite of deep leverage points with a systems perspective in the centre, and more shallow level actions in the periphery.

Definitely, more holistic approaches would be a valuable complement to forest scenarios traditionally focusing on wood yield carried out in Sweden, but which are being broadened to include biodiversity and other values, as well as risks and vulnerabilities affecting the provision of ecosystem services as well as commercial monetary values (Eriksson, 2021).

New drivers are emerging. Climate change may involve extreme temperatures and drought, strong winds and flooding, which can and must be eased through forest-based adaptations (Blumroder et al., 2021). For example, regulating services of land cover in terms of moderating and mitigating local temperatures are increasingly important (Gohr et al., 2021).

Hence, forests in densely populated regions could shift from providers of raw materials to mediation of extremes/ stabilization of ecosystems to support human well-being and health. Bringing back tree biomass into open landscapes is one scenario. In contrast, in Belarus, Ukraine or Russia urban and *peri*-urban forests are shrinking at a great pace as grey infrastructure and interests of investors in this is a much greater priority (Shkaruba et al., 2021). However, not all benefits of forest ecosystems can be measured using monetary valuation (Merlo and Croitoru, 2005). Therefore, also other currencies (e.g., biodiversity components (Noss, 1990); demography (e.g., Möller and Amcoff, 2018), and human well-being (e.g., MEA, 2005), are required.

4.2.3. Landscape stewardship and citizen movements

Landscape stewardship is "*a place-based, landscape-scale expression of broader ecosystem stewardship*" (Bieling and Plieninger, 2017:5) that aims at maintaining natural capital. This requires knowledge and skills to navigate the complexity of interactions within landscapes as socio-ecological systems (Partelow, 2018). The territorial organisation of social systems being in charge of ecosystems adds complexity. There are public (national, state, communal-local, district etc.) and privately owned forests (smallholders and large private forest estates, often influential 'former' noble families). Multifunctional landscapes require integration across sectorial silos, and at multiple levels of governance. There are also cultural differences regarding social capital forms and meeting places. Analysing 16 landscapes on the European continent, Angelstam et al. (2021a,b) highlighted the need to identify socio-ecological clusters in order to facilitate dialogue and avoid silos. This stresses the need for regionally and culturally adapted approaches to landscape stewardship. Also the structure of the human populations use profile matters. For example, Niedziałkowski and Shkaruba (2018) found that in Belarus seasonal dwellers from cities were more often concerned (and gave signals to competent authorities) about unwanted forestry practices than the local rural population. In Germany, a recent phenomenon in civil society is that people are unhappy with forest management, and have founded numerous citizen associations calling for participation, and an umbrella organisation on the national level (https://www.bundesbuergerinitiative-waldschutz.de/). Similarly, an active forest protection movement has emerged in Lithuania (https://puniossilas.lt/). There is a rich literature and practice documenting experiences of applying different landscape concepts and approaches (Angelstam et al., 2019). Key components include collaborative stakeholder engagement, evidence-based knowledge about states and trends of the biosphere, society and economy, step-wise iteration of successful problem-solving linked to adaptive leadership able to navigate in the social system (Dawson et al., 2017; Nikolakis and Innes, 2020).

4.2.4. Zonation through planning of entire landscape

There is extensive research (e.g., Polasky et al., 2008; Serrano-Ramírez et al., 2021), and implicit and explicit policy level agreement regarding water, landscape and biodiversity, on the effectiveness of zoning of landscapes, at different scales, to accomodate different portfolios of objectives (e.g., Nelson et al., 2009). This is consistent with policy about green infrastructure aimed at sustaining representative and functional habitat networks (e.g. Angelstam et al., 2020). Analogously, Andersson et al. (2013b) and Kareksela et al. (2013) proposed what could be called inverse spatial conservation prioritization. This implies identification at the landscape level of areas suitable for intensive wood production in areas with the highest economic and lowest ecological values. This aligns with studies of the opportunity for intensified wood production (Nilsson et al., 2011). An effective instrument for achieving a holistic view is integrated landscape approach and planning (Angelstam et al., 2019). However, such approaches need to be adapted to local and regional contexts in terms of governance legacies and land ownership cultures (Lazdinis et al., 2019; Angelstam et al., 2021b). Compiling demonstration examples about how zoning could be achieved in practice through a wide range of means that match different ownership contexts (e.g., Angelstam et al., 2020:12) can be disseminated step-wise and show how they can be matched with different local and regional social-ecological contexts.

For example, past widespread projects to drain excess water on forest and agrcultural land were actually built on an early form of landscaping where first open ditches and later culverted drainage systems were built by everyone in the landscape, and it was understood that individual actions contributed to the whole. Other Swedish systems for landscape planning are conservation for fishing, moose management areas and rural road societies. Similarly, a landscape perspective is neede to address cumulative effects of traditional land uses such as forestry for wood production, and new ones such as wind power parks, as well as their effects on nature-based tourism based on perceptions of wilderness and cultural woodlands. In contrast, forestry and forest policy focus on the stand scale. The government decided in 2013 that the Swedish EPA should develop a proposal of an action plan for green infrastructure at the regional level (Regeringen, 2014). However, some stakeholder groups reject segregated approaches.

4.2.5. Systems-based thinking to address wicked problems

Using the terms of Grint (2008), policy-makers have three types of problems: tame, critical and wicked. While for the first two, being more or less urgent to handle, there are well-established best-practices. In contrast, for wicked problems there is no consensus of the problem, and there is disagreement among actors and stakeholders. Nikolakis and Innes (2020:13) listed three components for tackling wicked problems. Along with collaborative governance and adaptive leadership (Section 4.2.3), holistic systems-based thinking is a necessary avenue.

Forestry developed in the 18th century as a cropping systems like agriculture (Knize and Romanyuk, 2006), and with linear decisions around wood yields and successional rotations. Today, however, forests and woodlands are expected to be managed for multiple objectives, and are increasingly subject to uncertainties in the biosphere, society and economy. This paradigm shift in policies affecting forests and woodlands has broadened the focal spatial extent from stands to landscapes, forced considerations to cascading and non-linear effects, and requires interactions among actors with different stakes (Messier et al., 2015).

The climate-forest nexus is a good example in which different perspectives about spatio-temporal domains exist in the context of carbon sequestration vs. storage, forestry intensification vs. biodiversity conservation, land-sharing vs. land-sparing supporting multifunctional landscapes, and among some actors' unwillingness towards holistic systems analyses. Achieving international commitments concerning mitigation and adaptation to climate change can be expected to increase rivalry among different land uses, and lead to increased conflicts of interest. Without a holistic view there is a risk that changes of some benefits will take place at the expense of other sustainability goals, such as conservation of biological diversity and cultural heritages values. Loss of such values can be costly or impossible to restore. It can also lead to failing to comply with international commitments. The strategy for a carbon neutral EU by 2050 relies on the circular economy, natural carbon sinks and lifestyle changes. Ultimately, zero emissions are not enough, instead CO_2 needs to be removed from the atmosphere. There are two hypotheses: (1) forests should not be harvested but sequester and store more carbon (both in biomass and in soil); and (2) forests should be used for products, which through substitution should reduce other emissions, and store carbon. This includes also bioenergy that substitutes fossil fuels, without storing carbon. Testing these hypotheses require cradle-to-grave accounting of CO_2, and consideration of all sources of sequestration and release, and for all land covers on and in the ground, and steps in production and value-chains (e.g., Camia et al., 2021; Grassi et al., 2021).

4.2.6. Coping with "Truth Decay"

Heated debates have become hotter with the growing role of "fake news" in rapidly evolving social media and technology systems (e.g., Allcott and Gentzkow, 2017; Shu et al., 2017). This also involves "truth decay", i.e. the diminishing roles of facts, data, and analyses in political and civic discourse (Kavanagh and Rich, 2018; Huguet et al., 2021). That facts become cherry-picked or less important may be attributed to the fact that the rivalry among different forest uses, and associated stakeholders groups, has become politically hotter as the demands of what forests should deliver increase. Creative book-keeping of the proportion of productive vs. unproductive forest land that is formally protected, voluntarily set aside at different scales, with different management, quality and functionality as green infrastructure can be used to create different narratives (Angelstam et al., 2020). Given the rivalry between transformation of near-natural forests to wood production landscapes, and application of different conservation instruments, it is important but not common to assess the net effect of pressures and responses in space and time (e.g., Angelstam and Manton, 2021). Tools and strategies for climate mitigation and adaptation is another example of how different narratives can be presented (Rummukainen, 2021). One example has to do with afforestation and reforestation, which are pushed by governments and corporations as politically gainful and publically accepted 'active' solutions, often overlooking potential damages to biodiversity or hydrological systems (Lee and Zhang, 2018; McGrath, 2020), whilst neglecting the need to safeguard still functional forests (Selva et al., 2020). In Russia, the government actively pushes the line of defence against the Green Deal and other carbon taxation or emission reduction initiatives saying that Russia's forest is underestimated in terms of its sequestration capacity, so its role as a carbon sink needs to be duly recognised, and then no structural changes in economy would be needed (Davydova, 2020; Khrennikova et al., 2021).

A variant of fake news and truth decay is that "knowledge is dangerous". For example, the recent Swedish forest policy review (SOU, 2020) evoked objections against the current focus on evidence-based decision-making. Surveys of high conservation values made by the Swedish Forest Agency have been stopped, there are requests that collected data showing the location of such sites should be deleted, and land owners should not be required to survey biodiversity values. Assessments of gaps in forest protection and functionality of green infrastructure should not be made. According to the forest sector coalition network, opposing an environmental coalition that supports EU environmental forest policy integration (sensu Sotirov et al, 2021), Sweden should thus make a new own 'green-washed' interpretation of the extent to which international policies and strategies, such as the EU Forest strategy (*European* Commission, 2021), are satisfied.

4.2.7. Towards a forest capital index

Assessing states and trends towards multifunctional forest landscapes requires an overall accounting of forest management, which takes into account all types of value creation within and among different value chains, but also costs in terms of subsidies and of damage creation. When considering weak vs. strong sustainability visions (Neumayer, 2003), all three bioeconomy visions identified by Bugge et al. (2016) remain limited in questioning monetary economic growth. Nevertheless, book-keeping about monetary costs and benefits can include different items. In contrast, Gross Domestic Product (GDP) is the current default standard for economic and social progress, and which does not distinguish activities enhancing from those reducing welfare. Reviewing shortcomings of GDP, Giannetti et al. (2015) concluded that really coping with concerns regarding sustainable development, progress indicators measured only in monetary or social terms are limited and restricted to the weak sustainability model, and must be complemented by biophysical indicators. There are, however, alternatives. The Genuine Progress Indicator (GPI) aims to evaluate the impact of policy proposals more comprehensively. For example, Kubiszewski et al. (2013) showed that while global Gross Domestic Product (GDP) increased more than three-fold since 1950, economic welfare, as estimated by the Genuine Progress Indicator (GPI), has actually decreased since 1978. The Gross National Happiness (GNH) Index (Ura et al., 2012) is another approach, and provides an overview of performance across nine domains (psychological wellbeing, time use, community vitality, cultural diversity, ecological resilience, living standard, health, education, good governance). Such approaches can be applied at any governance level provided that data are made available (e.g., Axelsson et al., 2013; Andersson et al., 2013a). This is consistent with the idea of a Forest Capital Index (Ullsten et al., 2004), which assesses the extent to which forest use is operating within safe boundaries (O'Neill et al., 2018), such as described in doughnut economy (Raworth, 2017).

4.2.8. Need for honest brokers

EU level processes leading to the biodiversity strategy for 2030, the Climate Law and Forest Strategy from 2021, have triggered intense activities among different stakeholder groups. This has led to creation of different narratives about how to cope with climate change, intense lobbying of different stakeholder groups, and debates over if and how forest landscapes should be planned and forests managed, and what different data sets tell about forest trends (Palahi et al., 2021; Ceccherini et al., 2021). The rivalry among different narratives can create deep trenches. This involves policy in terms of decisions about directions; politics as bargaining, negotiation and compromise; and science as the pursuit of knowledge. A key issue is if and how evidence-based knowledge connects to policy-makers, and the extent to which it can play a constructive role in different social-ecological contexts. In a business context, concerns about a company's business model are emerging, including the extent to which its products and services contribute to Environmental, Social and Governance (ESG) dimensions. This is thus also about a company's risk management. In their review of the effects of considering ESG on financial results Friede et al. (2015) concluded that long-term responsible investing should be important for all rational investors, and also better align investors' interests with the broader objectives of society. Stressing that decision-makers and scientists have choices concerning what role they play, Pielke (2007) identified a range of options individuals can consider when making decision about how to position themselves in relation to politics and policy. The four options pure scientist, science arbiter, issue advocate, and honest broker (or reflective practitioner (Clark, 2002)) are presented as a flow chart based on two levels of criteria. Regarding transformational change towards multifunctional landscapes, the decision-making context is not characterized by consensus of values and low uncertainty, and requires an expanded portfolio of choices. This means a call for honest brokers "*… that provide insight that expands the choices available to policy-makers and the public, perhaps in some cases showing the way past gridlock and political stalemate…*" (Pielke, 2007:152). However, this requires nonviolent action (*sensu* Sharp, 1973) also regarding the style of communication using social media.

5. Conclusions

Using the history of developing even-aged silviculture for industrial use in Europe, and with Sweden as a case study, this paper sets out to explore the necessary transition from forestry as a monocultural cropping system into sustainable forest management capable of maintaining multi-functional landscapes. Our use of multiple vantage points using the lenses of the biosphere, the society and the economy as nested systems can improve the understanding of forest landscapes as complex multi-level social-ecological systems. Besides moving to a landscape perspective and a focus on viable and resilient ecosystems, this requires an understanding of the dynamic roles of traditions and cultural legacies in social systems at various levels of governance and spatio-temporal scales. Trees, forests and forest landscapes reflect the combined result of perceptions, strategies and power relations maintained by a wide range of local, regional, national and international stakeholders and actors. The resulting practises of forest management are based on a rich sediment of knowledge, norms and social relations aquired in specific geographical contexts over long time. The required adaptation and mitigation to climate change introduces a new urgency at multiple levels. Climate change may involve extreme temperatures and drought, strong winds and flooding, which can and have to be eased through forest-based adaptations. The policy response, as well as the practices on the ground, must be forceful and at the same dynamic in time to address currently unknown trajectories that threaten resilience. Policy, governance and management must be adapted to a wide range of local and regional socio-ecological contexts, but also be able to confront local norms and practices, which are generally slow to change.

Focusing on Sweden as a case study we conclude that landscape governance needs to be matched by institutions affecting regulation, spatial planning, extension service, education, and monitoring in relation to performance targets. We highlight the rich literature on deep levers that can support transformative change towards multifunctional forests and woodlands. A key feature is to apply landscape concepts and approaches to promote evidence-based dialogue and placed-based collaborative learning. One key issue is that forested land is rarely being managed at a landscape level or with a landscape perspective. This is not beneficial, or even counterproductive, for the establishment of landscape based and ecosystem oriented forest management. In particular, cultural inertia of industrial even-aged forestry can hamper both incremental and transformative change. There are currently few incentives for landowners to apply a landscape perspective. However, forested landscapes are infused with effective institutions to handle other common resources that wood (i.e. hunting and fishing rights, servicing common logging roads, water regulation etc.), which can be expanded also to forest issues.

Industrial forestry in Europe has commonly been based on even-aged silviculture with re-generation based on the establishment of monocultural plantations. Currently, the EU challenges this and has put forward a new Biodiversity Strategy (2020), and a Climate Law and a Forest Strategy (2021), all implicitly questioning the even-aged Nordic Forestry Model. In Sweden, this is complemented with protests against the EU from industrial forestry actors and the government, as well as an extensive media cover and criticism of the Nordic Forestry Model by other stakeholder groups. This stresses the need for applying a diverse portfolio of forest managagement approaches which is adapted to biophysical, historic and land owner contexts as well as a appropriate policy instruments. A wide range of research representing various forest environments in many countries supports the notion of multi-functional landscapes as a necessary move to establish management models responding to the climate and biodiversity crises. This implies recognition of the landscape level as the key scale for stewardship and planning. A range of approaches to zoning aim at sustaining functional habitat networks that support human well-being and biodiversity conservation, while at the same time allowing for effective wood production in appropriate areas. However, this would require a transition of forest management systems to better support the integrity and resilience of both ecosystems and social systems.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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