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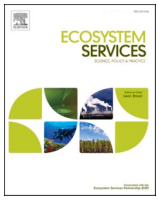

Understanding dynamics of forest ecosystem services governance: A socio-ecological-technical-analytical framework

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ABSTRACT

Little is known about the emergence and development of novel governance approaches for forest ecosystem services provision, what drives them, and how they can be fostered. Existing frameworks often deal with single aspects of resource management and thus fail to assess processes, multi-level influences, and interacting dimensions and factors in a system-based understanding. In this article, we introduce the conceptual foundation and an empirical application of an adapted Social-Ecological System framework with additional elements that builds on the idea of complex and interlinked social-ecological-technical-forestry-innovation systems that allows for the identification of key factors for revealing forest ecosystem services dynamics to understand the emergence and development of such governance innovations. The development and testing of the framework was based on six case studies for knowledge co-creation. To showcase its application, two governance innovations were examined: a voluntary carbon market payment scheme in Germany and a network approach for forest-pasture management in Italy. The application of the framework reveals required adaptations to improve innovation by systematically unpacking the system dimensions and identifying fostering and hindering factors and their interdependencies. We highlight the output of a sound system-based information basis that allows for purposeful innovation conditioning by policy makers, practitioners, and other related actors.

1. Introduction

Societies' impact on forest ecosystems has been growing in recent decades (Messier et al., 2019; Plieninger et al., 2016; Plieninger et al., 2012; Torralba et al., 2018; Wolfslehner et al., 2020). This is reflected in increasing and diversified socio-political and economic demands for forest goods and services, such as climate change mitigation, biodiversity conservation, and biomass for renewable energies (Bouwma et al., 2018). This dynamic environment of changing conditions and pressures on society and ecosystems requires innovative governance approaches for forest management systems and coordination in order to adapt to new circumstances (Secco et al., 2019).

Governance structures organise processes, determine objectives, set standards, influence motivations, initiate or reduce conflicts, and resolve disputes among actors (Eden & Hampson, 1997). Under innovative governance approaches, we understand novel forms of coordination in forest management and policy that allow for the sustainable provision of a wide range of forest ecosystem services (FES) and provide alternative income sources (see Mann et al., 2021, Maier et al., 2021, this issue). They include the establishment of new markets and payment schemes, for example, for carbon sequestration and biodiversity conservation. Further, they include novel actor alliances and networks – such as pure private or public private partnerships - that foster improved value chains (Feliciano et al., 2011; Åkerman et al., 2010). The development of the innovation itself is the result of the interaction of a wider network of actors that interact in a co-evolutionary process, where speed and direction are affected by several influences, such as the institutional environment (Hermans et al., 2015; Klerkx et al., 2010).

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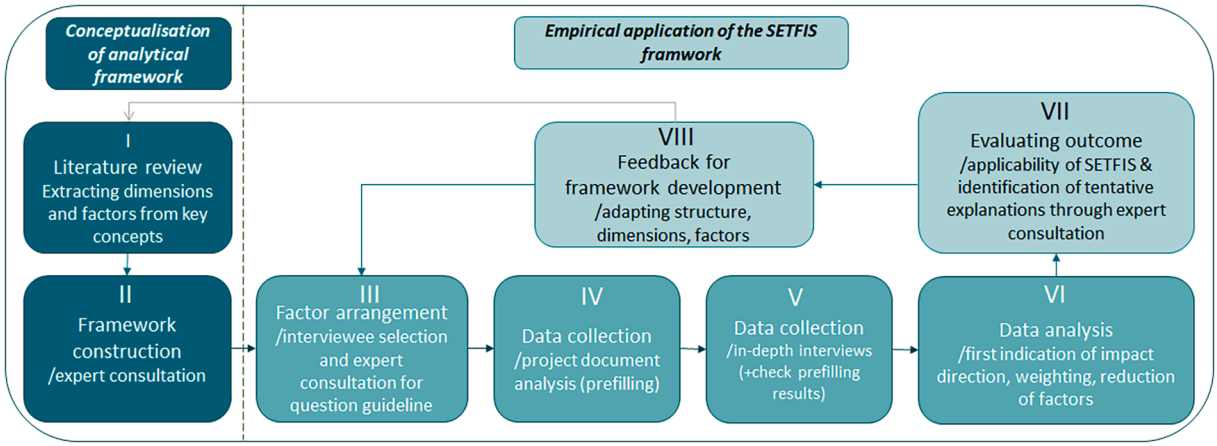

Fig. 1. Methodology for the development and application of SETFIS.

Forest management decisions are mostly driven by economic reasoning and market valuation of FES and are part of the dynamics and interactions within this system (Lindahl et al., 2017; Ruhl, 2010). Markets often fail to efficiently allocate natural resources due to the public goods character of many FES, externalities, unclear property rights, and insufficient knowledge and information (Loft et al., 2015; McGinnis & Ostrom, 2014). Furthermore, governance and business approaches focusing on FES provision, other than timber and non-timber forest products, are new to policy agendas and, so far, there has been little discussion and analysis of existing alternative coordination approaches in Europe (Maier et al., 2021, this issue). Although the impact of such approaches has been analysed in ex-post evaluation studies, there is still a knowledge gap in the occurrence, preconditions, and anticipated influence of such governance innovations (Bäcklund, 2009; EC, 2009; Theesfeld et al., 2010; Bowditch et al., 2020). Further, empirical evidence on links between the provision of FES, changes in supply and demand structures as well as governance approaches is rather limited and scattered (Gómez-Baggethun et al., 2010; Haines-Young & Potschin, 2011; Van Oudenhoven et al., 2012; Kluvankova et al., 2021).

Various approaches of system analysis exist to explain system dimensions or subsystems and their interactions that include, for example, the biophysical setting and the governance context, but also technological conditions and infrastructures. In our approach, we systematically connect them to forestry systems and forest governance innovations in order to understand the plethora of factors influencing FES provision. Many approaches of system analysis can be found in the scientific literature, for example analytical frameworks to explain social-ecological systems (SES) (Ostrom, 2009; McGinnis & Ostrom, 2014), socio-technical systems (Geels, 2004), changes in technological systems (Rip, 2018), economic systems (Doyne Farmer et al., 2012; Gunatilake et al., 1993), and innovation developments (Chaminade & Esquist, 2010). While each system approach focuses on specific analytical and methodological issues related to their subject of interest, all have in common to analyse specific sets of components and attributes that are interrelated and/or interacting in order to form the organic whole, a unity (Carlsson et al., 2002). This calls for a systemic approach to analyse and combine the various social, ecological, and technical system dimensions that may have an influence on the sustainable provision of FES and to integrate them in one more generic analytical framework. The objectives of this paper are twofold: First, we conceptualised the interlinked social-ecological-technical-forestry-innovation systems (SETFIS) framework to take complex context conditions into account which may influence the emergence and development of forest-related governance innovations; second, we empirically apply the analytical framework to test its ability to identify case-specific and cross-cutting factors that influenced the governance innovations in two case study regions in Germany and Italy. Both regions represent different types of governance innovations with differing biogeophysical, social, economic, and institutional context conditions. The case studies were part of the European Union (EU)-funded Horizon 2020 InnoForESt project that focused on governance innovation actions for FES.

The paper is structured as follows: In Section 2, we introduce the methods used to develop and apply the SETFIS framework. In Section 3, we present the conceptual basis for our system-based analytical framework for FES, which is then introduced as the SETFIS framework itself, and present the results of its application. Resulting implications for forest policy, economics, and research are highlighted and discussed in Section 4 before we close the paper with some concluding remarks.

2. Research methods

The conceptualisation and the application of the SETFIS framework consisted of eight steps, illustrated in Fig. 1, and detailed in Section 2.2. These consist of the literature review of key concepts to extract relevant dimensions and factors, the framework construction and factor arrangement for the interviews, followed by the data collection through project documents and interviews, and the data analysis to evaluate outcomes. Additionally, theoretical and empirical deliberations were made through a testing of the framework as an integral part of its development process to test its applicability in various institutional constellations. It was necessary to test whether the analysis of dimensions and factors derived from the selected theories and concepts provide meaningful information about key factors important for the further development of innovations. These feedback loops led to adaptations that helped to improve the applicability of the framework and the specific application to the area of forest-related governance innovations.

2.1. Conceptualisation of the analytical framework

The conceptualisation of the analytical framework for forest governance innovations departs from a set of theoretical approaches that address complex social-ecological, socio-technical, and innovation systems, as well as their interactions and dynamics.

Relevant approaches of system analysis were identified through a literature review using ISI Web of Science, Google Scholar, Livivo, EcoBiz, ScienceDirect, OECD Library, IFAF Berlin, and EBSCO as search engines. All databases were searched for the following keywords: “Social-Ecological System, Socio-Technical System, Socio-Ecological-Technical System, Innovation System, Forest Management System, Analytical Framework, Environmental Governance, and Governance of Change’’ and related search strings and combinations such as “Social-Ecological-Technical Systems”, and “Innovations in Governance’’. In

total, 242 peer-reviewed journal articles and books that provided reference and reports of applications of these approaches were collected and archived with Mendeley to facilitate further analysis. The database was then reduced to concepts that also take into account the interactions between system dimensions, resulting in a final selection of 65 papers to conceptualise the SETFIS framework. The guiding questions for the literature review were: (1) what relevant approaches of system analysis related to society, economy, ecology and transformation exist in the literature? (2) what system dimensions do the concepts and approaches focus on in order to analyse the emergence and development of governance innovations? (3) what factors potentially influence governance innovations during their emergence and development? and (4) what system dimensions are not or underrepresented and should be included for a holistic analysis?

We applied a structured way of looking for keywords, recommendations, and research findings to identify and explain the dimensions and factors, including the coding of factors from the SES framework related to forests and governance. The ones that seemed to be valuable in the relevant literature were compiled and sorted in a table with a total of six dimensions and 75 factors (Annex_1) through a consultation process with 12 researchers directly related to the InnoForESt project and working on FES in Europe. Through the consultation process, the different elements were defined, and factors were grouped within the respective dimensions. Additionally, nine experts for forestry governance innovations were consulted to review the outcome. The selection of these 21 experts aimed at balancing gender, scientific disciplines, hierarchical levels, and fields of practical and academic experience (Annex 3).

2.2. Empirical testing of the SETFIS framework

We used a total of six case studies to test and refine the framework. In the following, we present the empirical testing of the SETFIS framework based on two selected contrasting cases, using a case study approach (Crowe et al., 2011).

The first case study is that of a governance innovation in Germany. It is a voluntary greenhouse gas compensation scheme in the federal state of Mecklenburg-Western Pomerania. Tourists can buy an imaginary share, which is a certificate called Forest Share (original title: Waldaktie) at hotels in the region to offset parts of their vacation-related greenhouse gas emissions (Beringer et al., 2011; BMU and BMELV, 2010; Creutzig et al., 2015). The income generated through the sales of the Forest Shares is then invested into planting climate-resilient forests in the region.

The second case study is located in Fiera di Primiero, Italy. It comprises an approach that follows the idea of fostering an integrated forest-pasture management system in the mountains. The objective of this governance innovation is to improve the productivity of various activities for local landowners through the combination of traditional and innovative management approaches, as well as to integrate forest management with the preservation of social functions to reduce tensions between relevant actors through a network approach.

The testing of the framework was organised in four steps (Fig. 1). As a first step, all system dimensions and the corresponding factors of the analytical framework were translated into qualitative questions to elaborate with stakeholders that were part of the innovation process how the governance innovations in the case studies emerge, develop, and perform over time. The total set of 75 potentially influencing factors resulted in 82 questions (Annex_1). The interviewee selection was based on their close connection to the governance innovation at stake as the knowledge holder of the innovation. Interview partners reflect a range of expert perspectives from forest practice, public administration, non-governmental organisations, and sciences. The identification of relevant interview partners was supported by a dedicated governance context assessment and a stakeholder analysis that had been carried out in an earlier phase of the project (Aukes et al., 2020; Sattler, 2019; Schleyer et al., 2019). Second, the analysis of further project documents, such as the mapping of Europe's institutional landscape for FES provision, innovations and governance (Primmer et al., 2021; Primmer et al., 2018) and the analysis of replicability and upscaling potentials of governance innovations (Maier and Grossmann, 2019), further enabled pre-filling parts of the analytical framework with information on factors that have influenced governance innovation developments, which was validated later through the interviews.

Third, in-depth, semi-structured interviews (Longhurst, 2009) were conducted with selected key stakeholders via telephone, video calls, or in person. In total, 13 interviews (Annex_2) with stakeholders in all six case study regions were carried out. Of these, five interviews were conducted in the two selected case study regions that are described in this paper. The interviewees included a project manager of an environmental NGO, i.e. the Academy of Sustainable Development, Germany, a public administration representative from the Forest and Wildlife Service of the Autonomous Province of Trento, Italy, public foresters from Usedom, Germany, and Trentino, Italy, and a researcher from the University of Trento, Italy. The average duration of the interviews was 1.5 h, and they were carried out between July 2019 and January 2020.

Fourth, the transcribed interviews and secondary data from project documents were analysed to provide indications on similarities and differences on factors and conditions that had influenced forest governance innovation developments between case study regions, as well as interlinkages between the factors and their respective dimensions. This content analysis was performed by compiling the factors in an Excel table, including the description of how they played out in the development process and the qualitative strength of their influence from strong to weak as described by interviewees. In this vein, it was also assessed whether a specific factor had a fostering or hindering effect on the development of the governance innovation. Results were validated by the interviewees.

After the empirical application of the framework, a first evaluation of the framework through another round of expert consultation has been initiated. The same expert board of 21 project partners and scientists evaluated the factor influence. This resulted in a reduction of factors, i.e., those factors not considered at all in the interviews or factors that were similar in meaning were taken out, thus reducing the set of questions to 60–65, depending on the type of innovation. In turn, new factors that had not been identified in the literature review, but were revealed during the testing, were added to the list of factors and the framework adjusted accordingly. Based on the literature review and the feedback loop from the empirical testing, we conceptualised the SETFIS framework.

3. Results

3.1. Conceptual basis of the analytical framework

For the analysis of the factors and working conditions that have induced influence on forest governance innovations, first, a systems-based analytical framework was developed. As an outcome of the literature review, frameworks from SES analysis, and approaches that are rooted in sustainability transition research had been identified as relevant and formed the basis for conceptual integration. These approaches include different conceptualizations of systems and the respective subsystem dimensions, as well as their interdependencies (Binder et al., 2013a) and dynamics (Geels, 2002). Dynamics and linkages interdependencies among subsystem dimensions include economic factors and material or energy flows (Duchin and Steenge, 1999; Bouman et al., 2000; Kytzia, 2004); human activities and drivers of change with impact on ecosystems and/or FES (Redman, 1999; Antle et al., 2007); and identifying and modelling specific goods that are relevant for human-environment systems (Liu et al., 2007).

The well-established SES framework for environmental governance

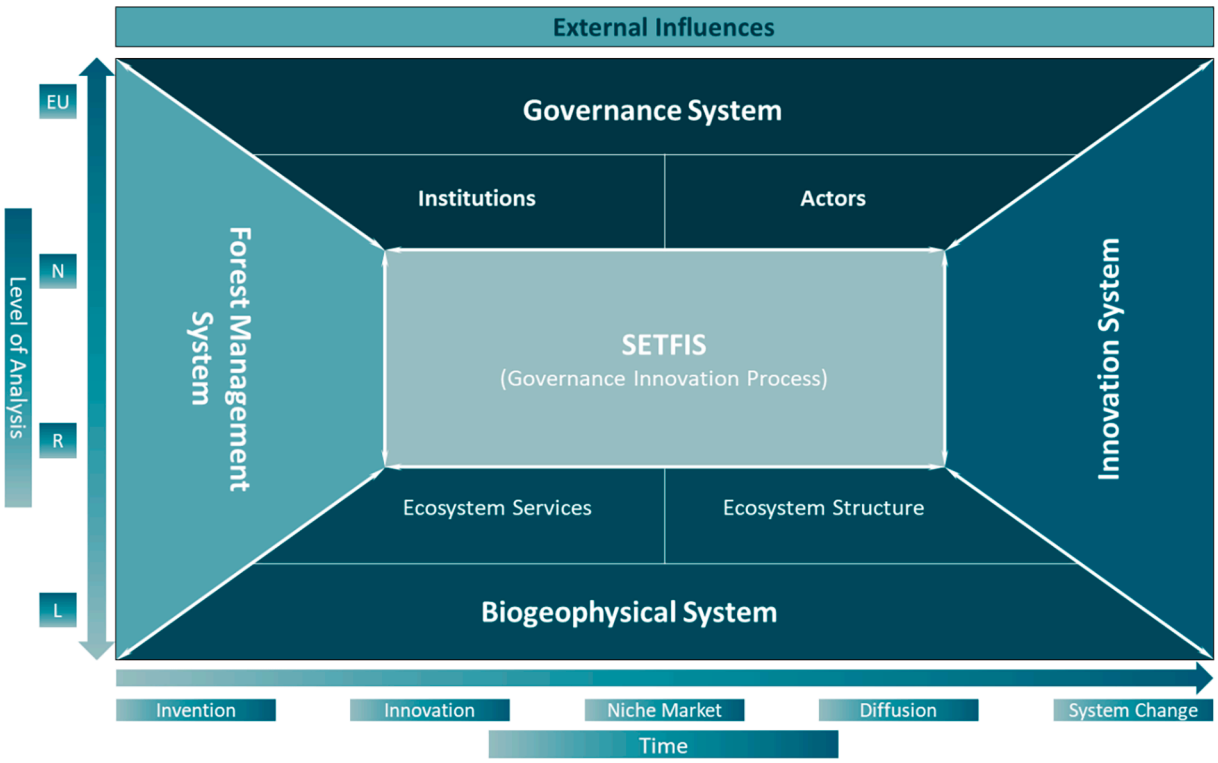

Fig. 2. The SETFIS framework for ecosystem-service governance-innovations.

research and organisation of collective action (Ostrom, 2011; McGinnis and Ostrom, 2014) serves as the conceptual backbone for the analytical framework. It highlights the interdependencies of social and biogeophysical systems. Social systems are conceptualised as governance systems including sets of institutions as formal and informal rules and actors and organisations, and biogeophysical systems that include resource systems and resource units in a multi-dimensional way. The SES framework serves to explain outcomes of ecosystem management by suggesting a hierarchy of potentially influencing context-relevant factors from the four subsystem domains (Binder et al., 2013a). Provision of FES relates directly to the dimensions of Ostrom's framework, here to the biogeophysical system structures and functions, as well as to the institutional setting and actors who derive benefits, and the values attributed to those benefits (Rinne and Primmer, 2015). Actors have diverse sets of norms (Ostrom, 2011) and use different behavioural forms to gain advantages under specific circumstances to co-create and to share knowledge and to - possibly - trigger innovation (Dolinska and d'Aquino, 2016). The combination of different factors shows interrelations of the system dimensions that characterise an action situation, which provides particular conditions for governance innovations to emerge and develop (McGinnis and Ostrom, 2014). The SES framework has become a widely used concept to guide planning, design, and management of SES towards sustainability, often pledging for collective action and co-designed natural resource management approaches and larger stakeholder inclusion. In a purposeful contrast to the traditional understanding of coordination by a central government, environmental governance refers to decision-making processes by which the use of common goods and services are decided upon by a wider range of stakeholders and societal actors operating not only alongside, but also often in collaboration with the state (Rival and Muradian, 2013). According to Ostrom and Basurto (2011), the effectiveness of collaborations depends largely on institutions, as the rules they rely upon, their enforcement, are formed and developed through related institutions.

However, the SES framework lacks important components such as time criteria to capture the developments over time or the level of analysis that relates to spatial multi-level influences on such innovations. It does not focus on innovation processes and dynamics. As a second conceptual backbone for the analytical framework, concepts from sustainability transition research are utilised such as socio-technical systems (STS) and the multi-level-perspective (Geels, 2002; Geels and Schot, 2007), together with a co-evolutionary understanding of innovation development and dynamics (Rip, 2012; Voß et al., 2009). Both strands of literature, i.e. the SES framework, STS and multi-level-perspectives point to particular factors that potentially influence the development of forest governance innovations and their performance. The SES framework considers the interacting influence of factors related to the ecosystem and its components, the actors, the governance system, and the broader (economic, institutional, social) context of the emergence and performance of hybrid modes of governance. Approaches from sustainability transitions add to the analysis as a larger set of socio-technical constellations are included and a focus on dynamics and patterns of stability and change integrated. Related innovation approaches will serve for the analysis to adopt a historical perspective for the identification of the working conditions of the different types of governance innovations over time. The analytical focus is on the dynamics of development processes and the interactions of governance innovations within contexts, acknowledging non-linear dynamics and uncertainties in complex systems (Geels, 2004). This includes questions of adaptation and change to intervene in SES/STS over time, for example, to secure or foster the provision of specific FES according to environmental degradation, societal requests, and shifting policy agendas (Binder et al., 2013a).

3.2. *Constructing the SETFIS analytical framework*

Based on the system understanding and subsystem dimensions identified previously, we derived our conceptual social-ecological-technical-forest-innovation (SETFIS) analytical framework (Fig. 2). SETFIS structures the system along linked subsystem dimensions, as well as their multi-level interactions and impacts on the emergence and development of forest-related governance innovations over time.

The framework focuses on 'forest governance innovation processes'

that can consist of specific events or series of action situations influenced by the dynamics of the system dimensions. The x-axis of Fig. 2 shows different stages of an innovation and the time dimension to be considered in the analysis. The y-axis points to the spatial level of analysis, ranging from local and regional to national and EU-level applications. Between the axes, the framework highlights the different system dimensions: the governance system comprising institutions and actors, the innovation system, the forest management system, and the biogeophysical system. Each system dimension is characterised by a set of factors (Annex_1), which potentially influence system dynamics and related governance innovations. Following, the dimensions of the framework and corresponding factors for the analysis of forest governance innovations for FES provision are detailed. Finally, the arrows in-between the dimensions demonstrate the dynamics and interrelations within the system.

3.2.1. System dimensions

Conceptually rooted in the SES framework, the framework consists of two central subsystem dimensions: **the governance system and the biogeophysical system**. The 'governance system' is defined as groups of actors, relations, and the formal and informal institutional setting that guide human decisions within an SES. 'Actors' focuses on 'who' influences innovation processes, and governance systems on 'how' actors - and therefore a concrete innovation process - are affected by relevant institutions. This includes the consideration of hierarchical levels of social scales from individuals, to groups or organisations, up to society and their interaction on the different levels (Binder et al., 2013b). This includes actors' diverse sets of multi-level values (van Riper et al., 2018), such as tradition, culture, behaviour of other actors, and ego (Duraiappah et al., 2013). The SES framework also adds access to information, knowledge of processes, actors' position within particular contexts, as well as benefits and costs for stakeholders, which are all largely organised by institutions and governance structures. Therefore, it is important to account for power asymmetries in such processes and provide spaces for participants' developing, discussing, and exchanging knowledge and experience in a co-creative manner (Dolinska and d'Aquino, 2016). Insights from environmental governance show that institutions help to concretise the governance system dimension because innovations are fostered or hindered by existing institutions, power relations, and path dependencies that limit change (Lindahl et al., 2017). Additional factors derived from environmental governance include different types of policy instruments, access of actors to decision-making, cross-level communication, cross-sector coordination, and rights, especially property rights. Furthermore, a monitoring system on FES is necessary to assess the influence of the governance innovation on the sustainable provision of FES (Gutsch et al., 2018), as well as to identify the potentially required support.

The biogeophysical system consists of the forest resource system and its resource units which are further subdivided into ecosystem structure and ecosystem services directly related to the area of the governance innovations. The biogeophysical dimension includes the FES in focus of the governance innovation under scrutiny, for example, carbon sequestration in the case of compensation schemes or the provision of FES bundles. It also contains the supporting and hindering conditions of the ecosystem itself. For example, the time component, in combination with tree composition, might have an impact on carbon sequestration, which matters depending on the case study (Alvarez et al., 2016; Gutsch et al., 2018).

As a third dimension, the **forest management system** is included in the analytical framework. It can be understood as a forestry-related socio-technical system, as it provides certain infrastructures, processes, and technologies for forestry operations. Additionally, the socio-technical component of forest management focuses on business practices in place and sheds light on forestry management requirements and training and helps to explain the central role of foresters. The dynamic subsystem forest management with a focus on the specific management implications also comprises finances, business strategies and management, transfer of management practices, and impact on related and/or surrounding regions and markets. Furthermore, forest management is shaped by a range of forest-related policies outside the forestry sector, such as agriculture, energy, biodiversity and nature conservation, climate protection, and rural development (Edwards and Kleinschmit, 2013; Winkel and Sotirov, 2016; McGinnis and Ostrom, 2014).

Insights from sustainability transition approaches and related innovation research (Asheim et al., 2011; Geels and Schot, 2007; Voß and Fischer, 2006) add a view on forestry as a multi-level innovation system, for example, for improving biomass production, harvesting and processing technologies, novel means for provision of non-timber FES, and new marketing and communication strategies (Mann et al., 2022). The fourth dimension of the analytical framework, **innovation system**, comprises innovation dynamics and interrelations between novel developments (the 'niche' level), their mainstreaming (the 'regime' level), and exogenous influences (the 'landscape' level), as well as related roles of actors. Many STS concepts further differentiate actors as innovation pioneers, enablers, and change agents (Geels, 2004). STS also adds key aspects of intentional innovation development that may lead to intended outcomes by processes of participation, experimentation, and monitoring.

In line with the SES framework, the dynamic centre on 'governance innovation processes' for ecosystem service provision are conceptualised as action arenas that comprise sequences and series of action situations, as well as the actors related to it. Within the governance innovation process, several factors are collected to identify specific innovation processes, but some factors were developed through identifying, analysing, and collecting several specific factor constellations, such as opportunity structures, scenario development, or the formation of visions and strategies during the analysis of the interviews.

3.2.2. Spatial levels, time scale, and external influences

The integration of the spatial and temporal components, 'level of analysis' and 'time scale', into SETFIS helps to sort and analyse the results over time and space. This is achieved by reconstructing the first steps of establishing governance innovations with a higher resolution that may provide information that supports the development of such innovations with help of identified fostering factors. This offers a basis for future comparisons of factors, dynamics, and patterns, in the case of reapplication of the framework within the same case study at different times. The SETFIS framework thus allows to retrospectively gain an understanding of dynamics of the emergence and development of forest governance innovations: what factors have influenced the innovation, from early ideas of its emergence and its developments until now, and what enabling conditions can foster their upscaling and upgrading potentials, i.e., what is needed for a similar innovation elsewhere, or an improved version of the innovation in the current context.

The last dimension integrated in the SETFIS framework is "external influences'. It distinguishes between internal and external influences and thereby helps to set boundaries and demonstrate interrelations and interdependencies between nature and society (Schleyer et al., 2017). Many external societal, economic, and political factors can influence the innovations; however, natural hazards and direct and indirect effects of climate change, which have an influence on ecosystem services provision, are central (Maroschek et al., 2009; Nelson et al., 2013) and need to be taken into account to reduce risks and observe opportunities.

3.3. Empirical testing of the SETFIS framework

For empirical testing of the explanatory power of the SETFIS framework, it has been tested in two governance innovation cases for FES provision in order to understand whether the analytical framework can help in understanding system change and to do so possibly identify first factors that influenced governance innovation development. The explanatory power of the framework is demonstrated by highlighting

factors that induce similar influence across the two cases, and those that appear to be case study specific. We present these factors following the SETFIS system logic of system dimensions, and their interrelations are revealed by highlighting factor (*italic*) interrelations within and across system dimensions.

As SETFIS application detected a large range of influences on governance innovation development from all system dimensions and components, we concentrate in the following on some major insights to illustrate the empirical testing of the concept. Display of results are organised along the dimension a) governance system, and the two components b) external influences, and c) local context conditions at spatial level. The final section of results d) highlights factors that were detected by SETFIS as being decisive which otherwise remain implicit.

3.3.1. The initial governance context

A closer look on the governance system at the *initial phase* of the governance innovation shows that several factors were supporting the development of the governance innovations. Especially *financial support* for the innovation through *local, national,* and *EU* played a crucial role. In the case of Fiera di Primiero, the governance innovation is strongly affected by *historical policy developments* in the 1950s. New *policies* in Italy, with a focus on industrialisation of urban areas, made the *management of forests* in mountainous areas non-profitable and caused migration to cities. Many forests became unmanaged, monocultural forests were common, and the traditional cultural landscape of pasture-forest-mountains could no longer be maintained. In the 1980s, however, the concept of *multifunctionality of forests* was increasingly recognized by policy and political decision makers. This included a more critical view of *low levels of biodiversity* in the monoculture forests that had developed in the region as a problem for management. This development led to *first projects* in the Primiero region to restore the traditional mixed forest stands and heterogeneous forest-pasture landscape, bringing several advantages for *FES provisioning* and businesses. Supported by the European Union's Agricultural Fund for Rural Development (*local funds*), the innovation leader in Primiero, the *Forestry and Fauna Service of the Autonomous Province of Trento*, was able to start such a project and develop a *network* of actors who were partly dependent on FES and interested in pushing forward such a governance innovation. This interlinked mixture of a dynamically changing *policy landscape* and a *collective interest* in FES provision in the region turned out to be decisive for stakeholders to *engage* in respective innovation development and renegotiation of responsibilities.

In the case of the Forest Share, the initial *policy objective* included awareness-raising for the importance of FES, as well as the general *impact of climate change* and related *events on society*. Here, the regional State Ministry for Agriculture, Environment, and Consumer Protection came up with the idea of developing an innovative compensation scheme to raise awareness *across the region*. This was combined with *positive effects for business*-related actors, for example in the tourism sector, and to work conjointly with the Forestry Office, Non-Governmental Organisations, and the Tourism Association of Mecklenburg-Western Pomerania.

3.3.2. External influences: Disruptive events and reactions

External influence such as disruptive events had direct effects on several factors of the biogeophysical system and led to several changes on factors of the innovation, governance and forest management system. More precisely, the SETFIS application revealed that external influences, especially *natural hazards*, had strong positive and negative impacts on both innovation developments, albeit with different effects on other factors. In 2018, the Vaia storm destroyed huge forest areas in Primiero (Giannetti et al., 2021). As a result, timber *market* prices went down, and the oversupply of storm timber affected some actor groups involved in the development of the innovation. These *disruptive events* have drastically changed the *priorities* and *motivations* of some *actors to contribute to innovation development.* Consequently, some *actors* left the innovation process, but at the same time, *new actors* joined as they identified negative influences from climate change that increased the likelihood of such natural hazards, and the potential impact on their businesses in the future *motivated* them to join and act. Interview partners in both regions highlighted the *adaptive capacity* of *strong innovation leaders* such as the Academy for Sustainable Development Mecklenburg-Western Pomerania in Germany and Forestry Service of Trento in Italy as a necessary precondition to deal with sudden external influences. The consequences of the storm in Primiero and the resulting dynamics within the system made it difficult for the Forestry Service of Trento *to lead* and to continue smoothly with the innovation development. Thus, they needed to be *adapted* immediately to the new circumstances in order not to lose more actors and to keep existing ones *motivated*. Keeping the *trust between actors* was already difficult before, because of *missing monetary incentives*, own costs, and loss of time for *workshop participation;* the changed priorities caused by the storm made it even more difficult to motivate participating actors to stay involved.

Additionally, stakeholders in Primiero experienced further external *societal influences* when the innovation development was already in progress. This was the case for example, when tourists who had developed some *awareness* of climate change issues came to the Primiero region and complained about the cutting of trees by foresters in the region.

The region that is covered by the Forest Share also experienced, and were shaped by *external influences* such as droughts and forest fires during the hot summers of 2018 and 2019. At the same time, Fridays for Future and the higher *societal awareness of the climate change discourse* became prominent (Sommer et al., 2021), but the momentum was not actively identified by the *innovation lead* as creating *synergies* between these societal dynamics and their own *innovation objective* in the region. Several *negative events*, such as declining sales and difficulties in finding appropriate areas to plant trees or to receive permission to do so, were necessary to provoke a reaction, e.g., a *change of strategy* and to *adapt* internal processes like *external workshop participants' constellations*. At the end of 2019, in the course of intensive discussions of future developments of the Forest Shares project among the main innovation leaders, representatives of Fridays for Future and the largest *customer* of the Forest Share, WEMAG, a local energy company, were invited to discuss further development and use options. The innovation leaders reacted very carefully in terms of changes of *participating actors*, especially from industry, innovation strategy, and objectives. In 2020, the Covid pandemic hit the two innovations and slowed down the developments of both, including the organisation of *workshops* and *meetings*. This followed to less dynamics related to *problem solving processes*, *actor interactions* and *decisions* on future developments, especially for the Forest Share.

3.3.3. The local context: Local development and ecosystem services dependency

The spatial level, the area where the governance innovation is embedded, presented several influences from the biogeophysical system and the resulting effects on the governance system and the conditions that create the local context. In both case study regions, *traditions, cultures, and habits* and therefore its *local situatedness* shaped the emergence of governance innovations as highlighted by SETFIS application. In the case of Forest Share, the close connection of the governance innovation to the region was seen as one of the unique selling propositions by interviewees that helped to attract new tourists, as well as 'binding' existing ones to the region by compensating within the same region and not somewhere else. Furthermore, the innovation lead of the Forest Shares are closely connected to the region, bringing their specific *knowledge* on *regional developments* into the design and required working conditions of the model of Forest Shares. In both cases, the participating *types of actors* who were responsible for the innovation management are a *mix of public and private actors*, while in the case of Primiero, the number of local small private companies *benefiting* from FES had the biggest share within the *actor constellation*. The focus on the *sustainable*

provision of FES made the governance innovation of an integrated forest-pasture management system in Primiero attractive to various companies from forestry, agriculture, and especially agroforestry such as cattle farming, as well as related professional fields such as dairy and meat production, timber production, and the important tourism sector within the region.

As an additional contextual particularity of the Primiero region, the innovative forest-pasture management approach had developed out of *traditions* and later *adapted to regional ecological and societal consequences* from historical developments. Today, the innovation lead is taking advantage of a combination of old and new forestry management techniques, such as cultural landscape restoration with a desired increase in biodiversity and diverse tree compositions instead of monocultures, as practised in recent decades, as well as of collaboration between the diverse set of actors.

At the same time, the local *biogeophysical conditions* affect the *specific FES focus* of the two governance innovations. The governance innovation in Primiero is tailored to mountain areas, existing monoculture forests, and their respective Forest Management System and is supported by the *demand of local enterprises* for specific provisional FES, including forest-related production and service companies. This diverse network of companies is partly dependent on FES that are provided by another local company to complement one another and would not be possible without a *bundle of FES* instead of a *single FES* focus.

This development has an effect on the locally specific *supply and demand of FES* in the Primero region as mentioned by the participating actors during SETFIS interviews. Both governance innovations have further potential to have an even stronger *impact on regional development* that leads to better *cooperation* and more efficient coordination of supply and demand of FES; for example, cooperation between landowners and beekeepers in Italy, or new actors with different objectives on FES joining coordination workshops of the Forest Share. When the Forest Share first emerged, the focus was on CO2 sequestration, along with other related FES. This was complemented by additional FES and related innovations that focussed on ES and made it more interesting for other actors to express their willingness to cooperate.

3.3.4. Further captured key factors for governance innovation: Entrepreneurship skills and monitoring system

Several factors were detected through SETFIS applications due to its pre-selected sets of factors that were otherwise not considered by main innovation leaders. In the following, we present some examples: First, *entrepreneurship and communication skills* matter in both innovations as interviewees highlight in the interviews. This factor contains, besides others, marketing skills, assessment of cost-benefit relations, and project management. Both innovation leaders mentioned the lack and suffered from missing marketing for further *development within the region*, including customers in the case of the Forest Share, and active in *lobbying* in both cases to emerge further in *regional political* circles and therefore to have a voice in political *decision making processes* for further support.

Second, interviewees at first did not see a reason to implement regular *monitoring instruments* to identify innovation development needs, conflicts or conflict potential. For example, in the Forest Share case, the local energy provider WEMAG became the biggest buyer of the Forest Shares. WEMAG was then providing Forest Shares as a welcome gift to new customers who signed contracts with WEMAG. This campaign ran counter to the interests of the Forest Share innovation lead as it posed the risk of being regarded as a case of *greenwashing* while the original target group were tourists. Potential *monitoring tools* could include *meetings* with internal and external actors or presenting outcomes from previous workshops served as *platforms to exchange* knowledge and experiences to discuss past, current and future developments. While Primiero contracted an external moderator in order to provide an outside view on further governance innovation developments that would not have been identified without. It also separated the connection of Forestry Service of Trento as the innovation leader with their individual *objectives* and *motivations* from the innovation development. The main *innovation leaders* of the Forest Share did not appoint such an external facilitator. *Regular meetings* to monitor and coordinate innovation activities did not happen in both regions with different impacts on innovation development. Meetings were rather organised ad-hoc, for example, when Forest Share development was stuck into the search for afforestation areas; the innovation team in Primiero was more hands-on when something had to be decided, a problem needed to be solved or a solution developed, meetings were organised to facilitate this.

In summary, the application of SETFIS helped to identify distinct influences of system dimensions and respective factors that have fostered or hindered the development of governance innovations in focus. SETFIS was useful as a heuristic tool not only to sort influences with help of deductively pre-structured system dimensions that correspond with sets of influencing factors, but also that the "factor library", the list of factors, was useful to systematically check influences with interviewees in an empirical way. In addition, system interactions became visible as well as commonalities and differences in factors that have fostered or hindered governance innovation development.

4. Discussion

In this section, we highlight and discuss three key aspects of the development and application of SETFIS: 1) The approach we used to develop SETFIS as an analytical framework that draws on elements of various concepts and theories that allows a structured analysis of governance innovations in forest ecosystems in the highly technical environment of European forests; 2) The insights gained from applying the framework; and 3) A methodological reflection on the SETFIS development.

4.1. Development of the SETFIS Framework: An integrated view on forestry innovation dynamics

Forests and governance innovation for the balanced provision of FES are a research field in which conceptual approaches from different disciplines and backgrounds intersect, i.e. SES thinking with technical systems and innovation research. However, none of these concepts fully meets the requirements of understanding governance innovations for the provision of FES in Europe. SETFIS aims to provide a holistic analytical framework that acknowledges complex system interactions and factor interdependencies when introducing governance innovations for FES provision. Similar to SES or STS approaches, SETFIS offers a multidimensional analytical structure that disaggregates a forestry innovation system into subsystem dimensions and their potentially influencing factors for empirical assessment.

This helps to set a basis for comparison of influences and working conditions of novel forms of governance innovations for FES provision, their analysis and modelling, and thus may help their future development by making innovators aware of past-present innovation dynamics and necessary system conditions, key factors, and requirements for development. An improved identification and demonstration of interrelations of factors and their related dimensions raise the level of detail and enrich the information basis. Building on such an understanding can help related actors to purposefully create innovation-friendly system conditions.

The SETFIS framework contributes to bridging two research lacunas: 1) it reconciles seemingly separate disciplines and sets of theories, and 2) it provides important contributions for forest governance research by including insights from innovation research (see Mann et al., 2021). It combines different theories and concepts to allow for an improved system view on, and better understanding of governance innovations for FES provision. Complex systems cannot be analysed, understood, and managed properly by concentrating only on a single dimension or scale (space, time, institutions, interactions, etc.). On the one hand,

combining individual theories and concepts strengthens the comprehensiveness of the system view on the innovation under scrutiny; however, on the other hand, it may cause a loss of depth because of the missing focus that the individual and more targeted concepts would offer. Additionally, it retains the advantage of having a common language within interdisciplinary teams, the importance of which was as highlighted by Ostrom (2014).

The presented factors in the previous results section encapsulate hidden processes of governance innovations by identifying the properties of the biogeophysical system that cross-societal and governance system boundaries. Therefore, those constellations have broader implications for the sustainability of SES by extending it with insights from innovation science (Duraiappah et al., 2013). The further combination with analytical lenses from STS and Forest Management Systems equips the SETFIS framework with additional characteristics that allow it to serve not only as a more comprehensive analytical tool (Binder et al., 2013b), but also to potentially support future innovation development.

The time scale in SETFIS helps provide insights into past, present, and eventually future innovation dynamics by making the dynamics and time component more explicit and allow for a more differentiated analysis. For example, in the case of Italy, insights were provided on how historical policy decisions had shaped the region and innovation. Understanding dynamics over time is essential to designing sequences of events like workshops including decision-making processes and other meetings that influence the development of the governance innovations.

Drawing on and integrating the SES frameworks explanatory power of formal and informal institutions helped to reveal the importance of both categories of institutions for innovation development. This was demonstrated in the case of Italy, with the bridging function of an intermediary between public and private, as well as internal and external actors, and, in the German case, by pointing to informal rules within the innovation team. Also, recognizing the importance of influences of and dependency on the biogeophysical system, were valuable aspects taken from the SES framework, because this system sets preconditions for the development of such innovations as well as traditions related to ecosystem management.

4.2. Application of the SETFIS framework: Cross-cutting and context-specific factors influencing governance innovations

The SETFIS framework has been applied to two specific governance innovations as cases that emerged in different regions in Europe. The analytical framework helps to structure the data from the interviews and document analysis that allows conducting a comparative analysis along the dimensions and subsequent factors. While some factors were more *context specific* such as biogeophysical conditions, traditions and ES in focus, others can be interpreted as *cross-cutting* factors that help to identify similar issues between different governance innovations. These include issues such as *initial funding, beneficiary, entrepreneurship and communication skills*. The results of the application of the framework can eventually further assists the innovation lead in identifying what could foster a certain governance innovation, showing what factor(s) can be influenced (e.g., institutions and actors) and what factor(s) (such as external influences) cannot or should not be manipulated.

It can be said that disrupting events have different levels of intensity on a closer or distant "influencing factor" that sends direct or indirect feedback to several or all dimensions and related factors. An example of this case is the change of actor constellation after the storm in Primiero, which influenced the stability of the network and overall strategy related to network composition and vision. This, again, may have future influences on the biogeophysical system if the selection of trees planted within a new forest changes and this could change preferences of participating businesses. Those disruptive events, such as natural hazards, as well as possible biotic disturbances (Irauschek et al., 2017; Thom and Seidl, 2016), such as Covid-19, had strong impacts on the innovation development, especially on the ecosystem structure and FES provided.

Fostering the actors' adaptive capacity to change may improve the resilience of the governance innovations. Adaptations can be understood as responses to risks or events (Smit and Wandel, 2006) and other obstacles that affect innovation development. In both case studies, the adaptive capacity to change and the respective responses to new circumstances or events such as natural hazards and vulnerabilities of forests to them (Bowditch et al., 2020) have been identified as important, but of different magnitudes. Whereas the Vaia storm prompted the actors in Primiero to act immediately (by offering a change in the direction of some innovation objectives, and providing new activities and innovation options to motivate and keep actors involved, and even reaching out to new ones), the actors involved in the Forest Share innovation required a longer series of negative events or developments (such as unproductive meetings or the emergence of outside 'competition') to act and adapt to the new circumstances.

The EU Rural Development Fund supported one of the previous projects and the initial idea of the governance innovation in Primiero can be seen as a successful instrument to promote innovative approaches and foster its emergence in the first place. SETFIS also helped to identify gaps within the development of the governance innovations at an early stage. In both regions, several factors were mentioned as being lacking or were not yet considered by the innovation lead. Therefore, policy makers or scientists can identify factors that can be used to support the design and implement instruments or other solutions, for example training courses on marketing or language skills. In detail, considering the high level of uncertainty of future environmental and social changes (Messier et al., 2019), SETFIS could contribute to reducing such uncertainties.

4.3. Methodological lessons learned

The abductive methodological approach employed in this study helped to systematically adapt dimensions, factors, and questions, but also to merge, delete, or extend the factor list with less bias and unwanted outcomes. The feedback loops within and among the iterative application of the framework through reviews and consultations by academics and related stakeholders in the regions advanced the analytical framework continuously. After the first analysis of the results of the SETFIS application, it remains unclear which factors are key influences for innovation development and important to focus on further analysis, policy recommendations, etc. Several supporting factors are indispensable when trying to understand the overall innovation development context and therefore specific characteristics, such as the factors 'type of actors' or the opportunity for 'creative destruction' (Kivimaa and Kern, 2016). Other factors that seem to be positive for one site, for example, the rising societal awareness of environmental issues, may support the selling of the Forest Shares, but may hinder or provide a source of conflict, as seen in Primiero.

The general SES framework offers a data organising structure and equal treatment of social and ecological systems and their dimensions. The SETFIS framework added data dimensions of Forest Management System and innovation science to this basic SES conceptualisation, for example the inclusion of time and the spatial level of analysis. The SETFIS framework therefore collects data through the questionnaire that can be potentially used in other analytical frameworks (Binder et al., 2013b) and potentially bias its results. We want to highlight the potential of the framework and encourage more in-depth assessment to clarify and expound the interrelationships more clearly as well as to improve its applicability. While the SETFIS framework seeks to understand complex development processes of governance innovations in general, its limited empirical basis is due to the small sample size, the focus on a particular case or issue of FES governance innovation, and, therefore, a particular actor composition that is shaped by public–private-partnerships limits the generalisability of the findings. Consequently, SETFIS needs to show its usefulness and analytical power

in further applications in other innovation contexts, possibly requiring, for example, additional business- and revenue-related factors.

5. Conclusions

The development of regionally differentiated and climate-adapted innovative forest governance approaches requires knowledge about how local biogeophysical conditions and networks of actors, together with the institutional setup and the diverse forest management systems, will interact and how they affect the sustainable provision of FES in the long-run. In this study, we develop an analytical framework that draws on a number of conceptual approaches that aim to understand innovative governance approaches within their socio-ecological-technical system in European forests. We integrate region-specific information of governance systems, including actors and institutions, information on biogeophysical conditions and forest management approaches and identify dynamics between them with respect to the emergence and development of specific governance innovations in two case study regions. Developing and applying such an analytic framework integrating various relevant system dimensions allows us to investigate governance innovations within forestry and related environments and provides a broad picture of diverse developments as input for a well-informed basis for future pathways.

The SETFIS framework attempts to deepen the understanding of FES and related governance innovations to show their development, as well as to identify influential factors that are context-dependent and can be used to clarify relationships with related concepts integrated. The framework is sufficiently broad to be linked to other concepts of innovative governance approaches or to be adapted to agricultural contexts by reconceptualising the forest management dimension. We used the 'concepts' as theory-driven foundations to underpin the framework and illustrate how innovation developments can be positioned within the framework in addition to the focus on FES.

The results add to a growing body of research on the links between social and ecological systems, combined with an innovation science perspective, and provide an important step towards the understanding of influences of and dynamics in such innovations within a SES.

We highlight the need for a sound system-based and co-created information basis that allows for purposeful innovation conditioning. This implies that this analytical framework serves as a tool to support collecting information on innovative approaches related to forestry. This is accomplished by analysing, explaining, and predicting system dimensions and influencing factors. This may help to identify requirements for governance innovations to emerge, develop, and work in an intended way to reduce uncertainty of the future through enhanced preparedness and guidance.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Carsten Mann reports financial support was provided by European Commission.

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Annex

Table A1
System dimensions, influencing factors and factor subgroup/examples (initial set and derived factors from interviews).

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	Factor	Question	Response (reduced version for publication)	Importance of factor (Important: x)	Impact of factor (Fostering: + Hindering: -)	Response (reduced version for publication)	Importance of factor (Important: x)	Impact of factor (Fostering: + Hindering: -)
1	Multi-Stakeholder Involvement (private companies, national/local publics, research institutes, NGO)	Who is involved in the innovation? Please describe the type of affiliation of actors, e. g. types: public, private, etc.	Multi-stakeholder	x	+	Multi-stakeholder	x	
2	Roles/functions/ rights	What are the different roles and functions of the involved actors for the innovation?	distributed across CG	x		distributed across CG	x	
3	Collaboration of actors in networks	What form of collaboration is used between actors? (networks, cooperatives, collaboration, loose, close…)?	tight connection	x	+	tight connection	x	

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Table A1 (*continued*)

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	Factor	Question	Response (reduced version for publication)	Importance of factor (Important: x)	Impact of factor (Fostering: + Hindering: -)	Response (reduced version for publication)	Importance of factor (Important: x)	Impact of factor (Fostering: + Hindering: -)
4	Flexibility of the network (change over time)	Has the actor constellation evolved and changed over time? If so, has this influenced the innovation?	Less flexible	x	-	Very flexible	x	
5	Regular meetings	Do regular meetings on the innovation exist between actors and regular are they held? Which issues are discussed?	Non-existent (on demand)			Non-existent (frequently)		
6	Beneficiary (public, private, research institute)	Which actor benefits from the innovation? Are they also dependent on the innovation?	Many (diverse)	x	+	Many (diverse)	x	
7	Changer/ categorization of actors (public/ public, private, research institute)	Who can change the innovation (e.g., rights to change the design and functioning, use and application, finances, others)?	Few (CG)	x	+ -	Many	x	+ -
8	Supporter/ categorization of actors (public, private, research institute)	Which other actors exist in the region (and beyond) who support the innovation? Who, why? (not actively involved)	Many (diverse)	x		Many (diverse)	x	
9	Enabler/ categorization of actors (public, private, research institute)	Which actor could enable certain processes that are important for the future development of the innovation?	Few (CG)	x		Many	x	
10	Hinderer - categorization of actors (public, private, research institute)	Which actors/groups that are against the innovation? Why?	Few (NGO, public)	x	-	Few		-
11	Exclusive access to core network	Are actors excluded from using the innovation (purposely/ unintentionally)? Who are these actors?	Exclusive	x	-	Non-exclusive	x	+
12	Availability of information	Who has access to information about the innovation? (everyone, certain stakeholder, etc.)	CG			Many	x	
13	Conflict (resolution)/ power relations	Are there any conflicts related to the innovation? What kind of conflict? How to deal with it?	Existent (content)	x		Existent (organisational)	x	
14	Lobbying for innovation/ power relations	Which lobbying activities have been realised in order to push the innovation?	Active	x		Active	x	
15	Public participation	How is public participation arranged within the innovation environment?	Closed	x		Open		

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Table A1 (*continued*)

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	**Factor**	**Question**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**
16	Actors' perception (acceptance and legitimacy)	How is the innovation perceived in its environment, e.g. the forestry sector, outside of the current innovation system?	Positive	x		Positive	x	+ -
17	Possible future actors	Do you plan to include further actors in the future? If so, who and why?	More exclusive		-	Open	x	+
GS - Institutions	**Factor**							
18	Impact of existing policies	Have the following policies and strategies an effect on the innovation: Forest Law, Natural Conservation Law, Biodiversity and/or Bioeconomy Strategy (state, national, EU, international level)?	Existent (varying)	x	-	Existent (varying)		+ -
19	Government support	Is the innovation supported by government/state? How?	Existent (high)	x		Existent (low)		
20	Sensitivity to policy-change	Where there any policy changes in the past that had a crucial influence on the innovation? Which ones and how (positive/negative)?	Existent (varying)			Existent (varying)		
21	Sensitivity to political-change (e.g. elections)	Have political changes affected the innovation like elections, parties etc.? If so, how?	Existent (varying)	x		Existent (varying)		+ -
22	Hindering policies (Hierarchy: hard/ soft regulations)	Which policies are hindering the functioning of the innovation, and why?	Existent (high)	x	-	Non-existent		
23	Supporting policy/ related policies	In contrast, what other policies could support the innovation, and how?	Existent (varying)			Compensation		
24	Traditions, culture, habits	Which specific traditions, cultures or habits support or hinder the innovation?	Regional importance	x		Regional importance	x	+
25	Decentralised decision making	Are decisions made central or decentral? How are/could be supportive to the innovation? (networks, PPP – PP – polycentric/hybrids)	Centralised	x	+ -	Decentralised	x	+
26	Markets support innovation	Which particular market conditions support or hinder the innovation?				FES dependency	x	+

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Table A1 (*continued*)

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	**Factor**	**Question**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**
27	Policy support needed	What could be changed in the institutional environment to help the innovation to develop? (support by government: creative destruction, incentives, subsidies, R&D,)	Marketing, supporting politicians	x	-	Incentives for participation		
28	*Innovation create new policy*	Could the innovation create a new policy setting/law etc.? If so, which?	Possible			Possible		
29	Monitoring and sanctioning rules existing (within I)	Which monitoring and sanctioning rules existent within the innovation environment?	Non-existent		-	Rudimentary developed		-
30	Advisory existent	Are there advisory instruments that support the development of the innovation?	Not existent		-	Partly existent	x	+
Biogeo-physical System	**Factor**							
31	ES Type	What type of Ecosystem Service (ES) does the innovation provide/ foster? (provision, regulating, supporting, cultural)	Carbon sequestration	x	+	Biodiversity	x	+
32	Contribution of innovation on ES	Where these ES provided also before the innovation existed as well? To a different degree?	Existent (high)	x	+	Existent (medium)	x	
33	Required conditions of ecosystem for functioning innovation	What particular biophysical/natural conditions are important for the functioning of the innovation?	Existent (high)	x		Existent (high)	x	
34	Influence of ES on innovation	How do changes in biophysical/natural conditions influence the innovation?	Existent (high)		+ -	Existent (high)		+ -
35	Inclusion of other ES benefiting from innovation	Which other ES provided by the biophysical environment that are out of scope of the innovation? (regulating, provisioning, cultural, supporting)	All categories	x	+	All categories	x	+
36	Improvement (or creation) of ES by innovation	Has the ecosystem/ES been improved by the innovation in relation to its objective set in the beginning? If so, how?	Existent (high)	x	+	Existent (high)	x	+

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Table A1 (*continued*)

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	**Factor**	**Question**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**
37	Possible improvement of biophysical conditions	How could the biophysical conditions be improved for ecosystem service provision?	Existent (high)	x	+	Existent (high)	x	+
38	Acute risks	Which acute risks for the ecosystem that can hinder the provision of ecosystem services?	Existent (high)	x	-	Existent (high)	x	-
Forest Managt. System	**Factor**							
39	FMS	Which particular forest management strategy necessary for the Innovation (type of FMS – clear cutting – changing)?	Reforestation	x	+	FPM	x	+
40	Infrastructure/ technologies required	Does the innovation require any particular infrastructure such as paths/networks, technologies, digital infrastructure, machinery etc.? If so, why? Change	Not required (just to access)			Not required (just to access)		
41	Certifications important to innovation	Does forest or other certification schemes play a role for the innovation (e.g. FSC, PEFC)? If so, how do they influence the innovation?	Not yet (region)			Not yet (region)		
42	Type of forest ownership	What kind of forest ownership is necessary for the innovation? (PPP, public, private, community based)	Public	x	+ -	Public, (private)	x	
43	(forest) Entrepreneurship required	Are specific (forest) entrepreneurship skills necessary for the innovation? If so, which ones? (accounting, calculating, law, etc.)	Business admin.	x	-	Business admin.	x	-
44	Management flexibility required	How flexible needs forest management system to be for the innovation to work?	Non-flexibility required			Flexibility required	x	
45	Direct sources of funding for the innovation (public, donation, private, science)	How is the innovation financed/financial structure?	Secured by public, science	x		Secured by public, science	x	
46	Indirect funding existing	Is there any external financial support or other types that could provide resources to the innovation?	Public			Public	x	+
47	Monitoring of ES/ FMS	How do monitoring systems of the related ecosystem services work, which are important for the innovation?	Existent	x	+	Partly existent		

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Table A1 (*continued*)

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	**Factor**	**Question**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**
48	Unintended effects	Which unintended effects on forest management by the innovation, or the other way?	Not evidend yet	x	+	Not evidend yet	x	+
49	Support via FM	How could changes in forest management support the innovation? Which ones?	Existent (high)	x	+	Existent (high)	x	+
50	Transferability of FMS	Can the required forest management system/strategies be transferred to other areas (region or countries)? Why or why not?	Existent (high)	x	+	Existent (high)	x	+
51	Development impact	Could it be possible to create any feasible impact on local/ regional/national/EU development in terms because of the innovation?	Existent	x	+	Existent (high)	x	+
Inno. System	**Factor**							
52	Source of initial idea important to innovation development	What was the initial idea for the innovation to be established?	Sensibilisation, CO2 sequestration	x	+	Restoring cultural landscape	x	+
53	Innovation-friendly environment for niche development (information, regulation, subsidies, incentives)	What is/was necessary to provide the required space for the innovation to work (regulations, actors, external processes)?	Regulation, communication/ media, subsidies	x	+	Communication, external funds, e. g. for collaboration	x	+
54	Fulfilment of principal main expectations	What were the main expectations concerning the outcomes of the innovation? Fulfilled?	Achieved (requires reinnovation)	x	n/a		n/a	n/a
55	Initial strategy/ change	Has the initial strategy of the innovation development been changed over time? How?	Required (strongly)	x	+	Required (partly)	x	n/a
56	Change of application scope	Has the application scope of the innovation changed over time? How? (local, regional, etc. – level of analysis)	Only region	n/a	n/a	More regions in future	x	+
57	Type of Innovation	How would you characterise the type of innovation? (Product innovation, process, service, market, social, policy, business, other) cut	Product (service)	n/a	n/a	Service	n/a	n/a
58	*Development stage*	How would you characterise the current development stage of the innovation?	Reinventing the innovation idea	n/a	-	Visioning	n/a	n/a

(*continued on next page*)

Table A1 (*continued*)

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	**Factor**	**Question**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**
59	*Control systems/ feedback loop to stakeholder of innovation system (monitoring, sanctioning)*	Are there any control systems, monitoring and evaluation procedures that provide feedback to the stakeholders of the innovation (feedback loops) and indicate emerging problems? If, how do they work?	Non-existent			Partly-existent		
60	Related (similar/ supporting) innovations	Do similar innovations exist (in the region)? Are they competing or supplementing each other? Or are they/ are there supporting innovation?	Existent (not-contacted)	x	+ -	Partly-existent (contacted)	x	
61	Prevention, not compensation	What would you like to improve in the future (application scope, functioning, impacts…) of the innovation?	Goal prevention, currently compensation	x	+	Becomes part		+
62	Barriers	What kind of barriers to the innovation have been recognized?	Policies, nature	x	-	Policies, financial resources	x	-
63	External support through InnoForESt	Is InnoForESt supporting the innovation so far? How (not)?	Existent		+	Existent		+
64	Open-ended or closed process (time)	Is the innovation seen as an open- or as a closed-innovation-process? (with or without an end of the innovation life)	Closed			Open		
External Influences	**Factor**							
65	Climate change, part of larger development (e.g. megatrend, past event, pressure)	Do global environmental crises such as global warming or biodiversity loss affect the innovation? If so, how?	Existent (CC)	x	-	Existent (CC)	x	+
66	External threat	What would be an external threat to the innovation? (social, political, economic)	Greenwashing (customers, NGOs)	x		Pandemic, awareness of CC	x	-
67	External markets	How could the innovation be affected by external markets?	Different products			Partly affected		-
68	Spill-over effects	Have positive/ negative externalities, even a transfer of the innovation, been recognized? If so, which ones? Improve	Similar innovations, exchange with InnoForESt	x	+	Positive effects on region	x	

(*continued on next page*)

Table A1 (*continued*)

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	**Factor**	**Question**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**	**Response (reduced version for publication)**	**Importance of factor (Important: x)**	**Impact of factor (Fostering: + Hindering: -)**
Gov. Inno. Process	**Factor**							
69	Vision developed (long-term)	What is your vision for the future of the innovation?	Reinnovate WA	x		Adapted through storm		
70	*Social knowledge*	How can the innovation be advertised to increase social knowledge/ acceptance?	Marketing needs to be improved	x	-		x	-
71	Short term goals	What are the upcoming decision and short term goals?	Rethinling content of innovation/ calculation, staff to be focussed on innovation	x		Direction of innovation, network management		
72	Learning curves	Have you noticed specific learning curves (increase of learning through experience) during the whole development of the innovation? How has it been noticed?	Existent (partly)	x	+	Existent (partly)		+
73	Shared definitions of goals, problems, visions	Are definitions of goals, problems and visions along the management of the innovation collectively understood?	Yes (difficult to maintain)	x	+	Yes (difficult to maintain)		
74	Radical Choices	Which radical choices to be decided in the future that effects the innovation? What about the past?	Change or end of innovation		+	Nothing due to Covid-19		-
75	*Opportunity structures and capable agents*	What needs to be changed in order to create opportunity structures and include capable agents (e.g. politicians, investors)?	New actors in CG required					
	New Factors - named directly by interviewees (x)							
76	Connection to local area / focus on region		x			x		
77	Motivation (individual connection to innovation)					x		
78	Business administration skills required		x			x		
79	Policy analysis support		x			x		
80	Own certification/ logo		x			x		
81	Language issues/ understanding					x		
82	Strong leader/ leading group and opennes		x			x		
83	Resilience analysis (include various factors)					x		

(*continued on next page*)

Table A1 (*continued*)

SETFIS	Factor Innovation Region		Germany			Italy		
GS - Actors	Factor	Question	Response (reduced version for publication)	Importance of factor (Important: x)	Impact of factor (Fostering: + Hindering: -)	Response (reduced version for publication)	Importance of factor (Important: x)	Impact of factor (Fostering: + Hindering: -)
84	Communication of FES ("killing trees")		x			x		
85	Innovation idea broaden-narrow		x			x		
86	Resources (travel, work compensation)					x		
87	Vision – short term goals - strategy		x			x		
88	Greenwashing threat		x					
89	Education		x			x		

Table A2
Dates of SETFIS Interviews.

Innovation Region	Date	Participants
Eisenwurzen, Austria	30.09.2019	2 Principal Researchers from university, Austria
	14.11.2019	Head of NGO, studia
Mecklenburg-Western Pomerania, Germany	11.06.2019	Head of NGO, Germany
	11.02.2020	Regional State Forester, Germany
Finland	25.10.2019	Director of Finish of Environmental institute, Finland SYKE
	12.11.2019	Principal Manager of forestry association, FFC
Primiero, Italy	25.07.2019	Principal Research of the university of Trento, Italy (UNITN)
	01.10.2019	2 Foresters from the Forestry and Fauna Service of the Autonomous Province of Trento) (Italy)
Čmelák, Slovakia	29.07.2019	principal manager from an NGO Hype (Slovakia)
	30.07.2019	Administration of "The Low Tatras National Park" Liptovský Hrádok
Gothenburg, Sweden	25.09.2019	project leader from a company (Universeum)
	12.12.2019	Principal researcher from University of LUND

Table A3
Overview expert group.

Experts (#)	Country	Gender (F = female, M = male, D = diverse)	Field of experience (FES, Forestry related)	Level of experience (a= <10 years, b= <15 years, c= >15 years)	Practical (P)/ academic (A) experience
1	Austria	F	FES	A	A
2	Austria	M	Forestry	B	P
3	Austria	M	FES	B	A
4	Czech Republic	M	FES,	A	A
5	Finland	F	FES	C	A
6	Finland	F	FES	C	A
7	Finland	M	Forestry	C	P
8	Germany	M	Forestry	C	P
9	Germany	M	FES	C	A
10	Germany	F	FES	A	A/P
11	Germany	M	Forestry	B	P/A
12	Italia	M	FES	B	A
13	Italia	F	Forestry	A	P/A
14	Italia	M	Forestry	C	P
15	Netherlands	M	FES	B	A
16	Netherlands	M	FES	A	A
17	Slovakia	F	FES	A	A
18	Slovakia	F	FES	C	A
19	Spain	F	FES	B	A
20	Sweden	F	Forestry	B	P
21	Sweden	F	FES	C	A

References

Åkerman, M., Kilpiö, A., Peltola, T., 2010. Institutional change from the margins of natural resource use: The emergence of small-scale bioenergy production within industrial forestry in Finland. Forest Policy Econ. 12 (3), 181–188. https://doi.org/10.1016/J.FORPOL.2009.09.018.

Alvarez, S., Ortiz, C., Díaz-Pinés, E., Rubio, A., 2016. Influence of tree species composition, thinning intensity and climate change on carbon sequestration in Mediterranean mountain forests: a case study using the CO2Fix model. Mitig. Adapt. Strat. Glob. Change 21 (7), 1045–1058. https://doi.org/10.1007/s11027-014-9565-4.

Antle, J.M., Stoorvogel, J.J., Valdivia, R.O., 2007. Assessing the economic impacts of agricultural carbon sequestration: Terraces and agroforestry in the Peruvian Andes. Agric. Ecosyst. Environ. 122 (4), 435–445. https://doi.org/10.1016/J.AGEE.2007.02.003.

Asheim, B.T., Smith, H.L., Oughton, C., 2011. Regional Innovation Systems: Theory, Empirics and Policy. Reg. Stud. 45 (7), 875–891. https://doi.org/10.1080/00343404.2011.596701.

Voß, J.P., Smith, A., John, G., 2009. Designing long-term policy: Rethinking transition management. Policy Sci. 42, 275–302. https://doi.org/10.1007/s11077-009-9103-5.

Aukes, E., Stegmaier, P., Schleyer, C. (Eds.), 2020. Set of reports on CINA workshop findings in case study regions, compiled for ongoing co-design and knowledge exchange. InnoForESt Deliverable 4.2. Eberswalde: HNEE. https://innoforest.eu/wp-content/uploads/innoforest-deliverable-4_2.pdf (accessed 11 February 2021).

Bäcklund, A.K., 2009. Impact assessment in the European Commission - a system with multiple objectives. Environ. Sci. Policy 12 (8), 1077–1087. https://doi.org/10.1016/j.envsci.2009.04.003.

Beringer, T., Lucht, W., Schaphoff, S., 2011. Bioenergy production potential of global biomass plantations under environmental and agricultural constraints. GCB Bioenergy 3 (4), 299–312. https://doi.org/10.1111/j.1757-1707.2010.01088.x.

Binder, C.R., Bots, P.W.G., Hinkel, J., Pahl-Wostl, C., 2013. Comparison of Frameworks for Analyzing Social- ecological Systems, 18(April 2015). https://doi.org/10.5751/ES-05551-180426.

Binder, C.R., Hinkel, J., Bots, P.W.G., Pahl-Wostl, C., 2013b. Comparison of Frameworks for Analyzing Social-ecological Systems. Ecol. Soc. 18 (4), art26. https://doi.org/10.5751/ES-05551-180426.

BMU, BMELV, 2010. Nationaler Biomasseaktionsplan für Deutschland - Beitrag der Biomasse für eine nachhaltige Energieversorgung. Retrieved from. https://www.biomasse-nutzung.de/wp-content/bilder/Nationaler-Biomasseaktionsplan.pdf.

Bouman, M., Heijungs, R., van der Voet, E., van den Bergh, J.C.J.M., Huppes, G., 2000. Material flows and economic models: an analytical comparison of SFA, LCA and partial equilibrium models. Ecol. Econ. 32 (2), 195–216. https://doi.org/10.1016/S0921-8009(99)00091-9.

Bouwma, I., Schleyer, C., Primmer, E., Winkler, K.J., Berry, P., Young, J., Carmen, E., Špulerová, J., Bezák, P., Preda, E., Vadineanu, A., 2018. Adoption of the ecosystem services concept in EU policies. Ecosyst. Serv. 29, 213–222. https://doi.org/10.1016/j.ecoser.2017.02.014.

Bowditch, E., Santopuoli, G., Binder, F., del Río, M., la Porta, N., Kluvankova, T., Lesinski, J., Motta, R., Pach, M., Panzacchi, P., Pretzsch, H., Temperli, C., Tonon, G., Smith, M., Velikova, V., Weatherall, A., Tognetti, R., 2020. What is Climate-Smart Forestry? A definition from a multinational collaborative process focused on mountain regions of Europe. Ecosyst. Serv. 43, 101113. https://doi.org/10.1016/j.ecoser.2020.101113.

Carlsson, B., Jacobsson, S., Holmen, M., Rickne, A., 2002. Innovation systems: Analytical and methodological issues. Res. Policy 31 (2), 233–245. https://doi.org/10.1016/S0048-7333(01)00138-X.

Chaminade, C., Esquist, C., 2010. Rationales for Public Policy Intervention in the Innovation Process: Systems of Innovation Approach. Chapters.

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., Sheikh, A., 2011. The case study approach. BMC Med. Res. Methodol. 11 (1).

Creutzig, F., Ravindranath, N.H., Berndes, G., Bolwig, S., Bright, R., Cherubini, F., Chum, H., Corbera, E., Delucchi, M., Faaij, A., Fargione, J., Haberl, H., Heath, G., Lucon, O., Plevin, R., Popp, A., Robledo-Abad, C., Rose, S., Smith, P., Stromman, A., Suh, S., Masera, O., 2015. Bioenergy and climate change mitigation: an assessment. GCB Bioenergy 7 (5), 916–944.

Dolinska, A., d'Aquino, P., 2016. Farmers as agents in innovation systems. Empowering farmers for innovation through communities of practice. Agric. Syst. 142, 122–130. https://doi.org/10.1016/j.agsy.2015.11.009.

Doyne Farmer, J., Gallegati, M., Hommes, C., Kirman, A., Ormerod, P., Cincotti, S., Sanchez, A., Helbing, D., 2012. A complex systems approach to constructing better models for managing financial markets and the economy. Eur. Phys. J. Spec. Topics 214 (1), 295–324. https://doi.org/10.1140/epjst/e2012-01696-9.

Duchin, F., Steenge, A.E., 1999. Input Output Analysis. Technology and the Environment, Chapters https://ideas.repec.org/h/elg/eechap/801_68.html.

Duraiappah, A., Asah, S., Brondizio, E., Hunter, L., Kosoy, N., Subramaniam, S., 2013. Managing Biodiversity is About People Table of Contents, 2013(April), 1–34. Retrieved from. https://www.researchgate.net/publication/262800309_Managing_Biodiversity_is_About_People.

Eden, L., Hampson, F.O., 1997. Clubs are Trump: The Formation of International Regimes in the Absence of a Hegemon. In: Hollingsworth, J.R., Boyer, R. (Eds.), Contemporary Capitalism. Cambridge University Press, Cambridge, pp. 361–394. https://doi.org/10.1017/CBO9781139174701.015.

Edwards, P., Kleinschmit, D., 2013. Towards a European forest policy - Conflicting courses. For. Policy Econ. 33, 87–93. https://doi.org/10.1016/J.FORPOL.2012.06.002.

European Commission, 2009. Impact assessment guidelines. Retrieved from. https://ec.europa.eu/smart-regulation/impact/commission_guidelines/docs/iag_2009_en.pdf.

Feliciano, D., Slee, B., Weiss, G., Matilainen, A., Rimmler, T., 2011. The contribution of leader to the implementation of innovative forest-related projects. In: Weiss, G., Pettenella, D., Ollonqvist, P., Slee, B. (Eds.), Innovation in forestry: territorial and value chain relationships. CABI, Wallingford, pp. 87–100.

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Res. Policy 31 (8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8.

Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. Res. Policy 33 (6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015.

Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Policy 36 (3), 399–417. https://doi.org/10.1016/J.RESPOL.2007.01.003.

Giannetti, F., Pecchi, M., Travaglini, D., Francini, S., D'Amico, G., Vangi, E., Cocozza, C., Chirici, G., 2021. Estimating VAIA Windstorm Damaged Forest Area in Italy Using Time Series Sentinel-2 Imagery and Continuous Change Detection Algorithms. Forests 12 (6), 680. https://doi.org/10.3390/f12060680.

Gómez-Baggethun, E., de Groot, R., Lomas, P.L., Montes, C., 2010. The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. Retrieved from Ecol. Econ. 69 (6), 1209–1218. http://bit.ly/2lnUgiA.

Gunatilake, H.M., Senaratne, D.M.A.H., Abeygunawardena, P., 1993. Role of non-timber forest products in the economy of peripheral communities of knuckles national wilderness area of Sri Lanka: A farming systems approach. Econ. Bot. 47 (3), 275–281. https://doi.org/10.1007/BF02862294.

Gutsch, M., Lasch-Born, P., Kollas, C., Suckow, F., Reyer, C.P.O., 2018. Balancing trade-offs between ecosystem services in Germany's forests under climate change. Environ. Res. Lett. 13 (4), 045012.

Haines-Young, R., Potschin, M., 2011. Common International Classification of Ecosystem Services (CICES): 2011 Update. Expert Meet. Ecosyst. Accounts 1–17. https://doi.org/10.1016/B978-0-12-419964-4.00001-9.

Hermans, F., Klerkx, L., Roep, D., 2015. Structural Conditions for Collaboration and Learning in Innovation Networks: Using an Innovation System Performance Lens to Analyse Agricultural Knowledge Systems 21 (1), 35–54.

Irauschek, F., Rammer, W., Lexer, M.J., 2017. Can current management maintain forest landscape multifunctionality in the Eastern Alps in Austria under climate change? Reg. Environ. Change 17 (1), 33–48. https://doi.org/10.1007/s10113-015-0908-9.

Kivimaa, P., Kern, F., 2016. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Res. Policy 45 (1), 205–217. https://doi.org/10.1016/j.respol.2015.09.008.

Klerkx, L., Aarts, N., Leeuwis, C., 2010. Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment. Agric. Syst. 103 (6), 390–400. https://doi.org/10.1016/J.AGSY.2010.03.012.

Kluvankova, T., Nijnik, M., Spacek, M., Sarkki, S., Perlik, M., Lukesch, R., Melnykovych, M., Valero, D., Brnkalakova, S., 2021. (in review) Social innovation for sustainability transformation and its diverging development paths in marginalised rural areas. Sociol. Rural. 61 (2), 344–371.

Kytzia, S., 2004. Material Flow Analysis as a Tool for Sustainable Management of the Built Environment. In: Koll-Schretzenmayr, M., Keiner, M., Nussbaumer, G. (Eds.), The Real and Virtual Worlds of Spatial Planning. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 281–298.

Lindahl, K.B., Sandström, C., Sténs, A., 2017. Alternative pathways to sustainability? Comparing forest governance models. For. Policy Econ. 77, 69–78. https://doi.org/10.1016/j.forpol.2016.10.008.

Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H., Taylor, W.W., 2007. Complexity of coupled human and natural systems. Science 317 (5844), 1513–1516. https://doi.org/10.1126/SCIENCE.1144004.

Loft, L., Mann, C., Hansjürgens, B., 2015. Challenges in ecosystem services governance: Multi-levels, multi-actors, multi-rationalities. Ecosyst. Serv. 16, 150–157. https://doi.org/10.1016/j.ecoser.2015.11.002.

Longhurst, R., 2009. Interviews: In-Depth, Semi-Structured. International Encyclopedia of. Human Geogr. 580–584 https://doi.org/10.1016/B978-008044910-4.00458-2.

Maier, C., Hebermehl, W., Grossmann, C.M., Loft, L., Mann, C., Hernández-Morcillo, M., 2021. Innovations for securing Forest Ecosystem Service provision in Europe – A systematic literature review. Ecosyst. Serv. 52, 101374.

Maier, C., Grossmann, C., 2019. D6.2 Interim Report on Replicability and Upscaling Potentials of Governance Innovations (favoring provisioning and financing of forest ecosystem services). InnoForESt, Deliverable 6.2. Eberswalde: HNEE. https://innoforest.eu/wp-content/uploads/innoforest-deliverable-6_2.pdf (accessed 11 February 2021).

Mann, C., Hernández-Morcillo, M., Primmer, E., Bussola, F., Falco, E., Geneletti, D., Dobrowolska, E., Grossmann, C.M., Bottaro, G., Schleyer, C., Stegmaier, P., Kluvankova, T., Garcia, G., Lovrić, M., Torralba, M., Plieninger, T., Winkel, G., 2022. Governance Innovations for forest ecosystem service provision – Insights from an EU-wide survey. J. Environ Sci. Policy 132, 282–295. https://doi.org/10.1016/j.envsci.2022.02.032.

Mann, C., Loft, L., Hernández-Morcillo, M., 2021. Assessing forest governance innovations in Europe: Needs, challenges and ways forward for sustainable forest ecosystem service provision. Ecosyst. Serv. 52, 101384.

Maroschek, M., Seidl, R., Netherer, S., Lexer, M.J., 2009. Climate change impacts on goods and services of European mountain forests. In. Retrieved from Unasylva 60, 76–80. http://www.fao.org/3/i0670e/i0670e16.htm.

McGinnis, M.D., Ostrom, E., 2014. Social-ecological system framework: Initial changes and continuing challenges. Ecol. Soc. 19 (2) https://doi.org/10.5751/ES-06387-190230.

Messier, C., Bauhus, J., Doyon, F., Maure, F., Sousa-Silva, R., Nolet, P., Mina, M., Aquilué, N., Fortin, M.J., Puettmann, K., 2019. The functional complex network approach to foster forest resilience to global changes. For. Ecosyst. 6 (1), 1–16. https://doi.org/10.1186/s40663-019-0166-2.

Nelson, E.J., Kareiva, P., Ruckelshaus, M., Arkema, K., Geller, G., Girvetz, E., Goodrich, D., Matzek, V., Pinsky, M., Reid, W., Saunders, M., Semmens, D., Tallis, H., 2013. Climate change's impact on key ecosystem services and the human well-being they support in the US. Front. Ecol. Environ. 11 (9), 483–893. https://doi.org/10.1890/120312.

Ostrom, E., 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325 (5939), 419–422. https://doi.org/10.1126/SCIENCE.1172133.

Ostrom, E., 2011. Background on the Institutional Analysis and. Policy Stud. J. 39 (1), 7–27. https://doi.org/10.1111/j.1541-0072.2010.00394.x.

Ostrom, E., Basurto, X., 2011. Crafting analytical tools to study institutional change. J. Institutional Econ. 7 (3), 317–343. https://doi.org/10.1017/S1744137410000305.

Plieninger, T., Draux, H., Fagerholm, N., Bieling, C., Bürgi, M., Kizos, T., Kuemmerle, T., Primdahl, J., Verburg, P.H., 2016. The driving forces of landscape change in Europe: A systematic review of the evidence. Land Use Policy 57, 204–214. https://doi.org/10.1016/j.landusepol.2016.04.040.

Plieninger, T., Schleyer, C., Schaich, H., Ohnesorge, B., Gerdes, H., Hernández-Morcillo, M., Bieling, C., 2012. Mainstreaming ecosystem services through reformed European agricultural policies. Conserv. Lett. 5 (4), 281–288. https://doi.org/10.1111/j.1755-263X.2012.00240.x.

Primmer, E., Varumo, L., Krause, T., Orsi, F., Geneletti, D., Brogaard, S., Aukes, E., Ciolli, M., Grossmann, C., Hernández-Morcillo, M., Kister, J., Kluvánková, T., Loft, L., Maier, C., Meyer, C., Schleyer, C., Spacek, M., Mann, C., 2021. Mapping Europe's institutional landscape for forest ecosystem service provision, innovations and governance. Ecosyst. Serv. 47, 101225. https://doi.org/10.1016/J.ECOSER.2020.101225.

Primmer, E., Orsi, F., Varumo, L., Krause, T., Geneletti, D., Brogaard, S., Loft, L., Meyer, C., Schleyer, C., Stegmaier, P., Aukes, E., Sorge, S., Maier, C., Grossmann, C., Sarvasova, Z., Kister, J., 2018/2019. Mapping of forest ecosystem services and institutional frameworks, draft report. InnoForESt, Deliverable 2.1. Eberswalde: HNEE. https://innoforest.eu/wp-content/uploads/innoforest-deliverable-2_1.pdf (accessed 11 February 2021).

Redman, C.L., 1999. Human impact on ancient environments. University of Arizona Press, ISBN-10:‎0816519633.

Rinne, J., Primmer, E., 2015. A Case Study of Ecosystem Services in Urban Planning in Finland: Benefits, Rights and Responsibilities. J. Environ. Plann. Policy Manage. 7200 (July), 1–20. https://doi.org/10.1080/1523908X.2015.1076721.

Rip, A., 2012. The Context of Innovation Journeys. Creativity Innov. Manage. 21 (2), 158–170. https://doi.org/10.1111/j.1467-8691.2012.00640.x.

Rip, A., 2018. Processes of Technological Innovation in Context – and Their Modulation. Springer VS, Wiesbaden, pp. 49–73.

Rival, L., Muradian, R., 2013. Governing the Provision of Ecosystem Services Vol. 4. https://doi.org/10.1007/978-94-007-5176-7.

Ruhl, J.B., 2010. Ecosystem Services and Federal Public Lands: Start-up Policy Questions and Research Needs. Duke Environ. Law Policy Forum 20. https://scholarship.law.vanderbilt.edu/faculty-publications/464.

Sattler, C., 2019. Mixed method matching analysis. Suggested methods to support the development and matching of prototypes to the different Innovation Regions. InnoForESt Deliverable 4.1. HNEE, Eberswalde accessed 11 February 2021.

Schleyer, C., Lux, A., Mehring, M., Görg, C., 2017. Ecosystem Services as a Boundary Concept: Arguments from Social Ecology. Sustainability 9 (7), 1107. https://doi.org/10.3390/su9071107.

Schleyer, C., Stegmaier, P., Klingler, M., Kister, J., Aukes, E.J., 2019. Report on stakeholders' interests, visions, and concerns. InnoForESt, Deliverable 5.2. Eberswalde: HNEE. https://innoforest.eu/wp-content/uploads/innoforest-deliverable-5_2.pdf (accessed 11 February 2021).

Secco, L., Pisani, E., Masiero, M., Pettenella, D., 2019. Social and Technological Innovations in Forestry. In Forestry in the Midst of Global Changes (pp. 317–346). CRC Press. https://doi.org/10.1201/b21912-18.

Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Global Environ. Change 16 (3), 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008.

Sommer, M., Rucht, D., Haunss, S., Zajak, S., n.d. Fridays for Future. Retrieved September 27, 2021, from https://protestinstitut.eu/ipb-working-papers.

Theesfeld, I., Schleyer, C., Aznar, O., 2010. The procedure for institutional compatibility assessment: ex-ante policy assessment from an institutional perspective. J. Institutional Econ. 6 (3), 377–399. https://doi.org/10.1017/s1744137410000056.

Thom, D., Seidl, R., 2016. Natural disturbance impacts on ecosystem services and biodiversity in temperate and boreal forests. Biol. Rev. Camb. Philos. Soc. 91 (3), 760–781. https://doi.org/10.1111/brv.12193.

Torralba, M., Fagerholm, N., Hartel, T., Moreno, G., Plieninger, T., 2018. A social-ecological analysis of ecosystem services supply and trade-offs in European wood-pastures. Sci. Adv. 4 (5) https://doi.org/10.1126/sciadv.aar2176.

Van Oudenhoven, A.P.E., Petz, K., Alkemade, R., Hein, L., De Groot, R.S., 2012. Framework for systematic indicator selection to assess effects of land management on ecosystem services. Ecol. Ind. 21, 110–122. https://doi.org/10.1016/j.ecolind.2012.01.012.

Van Riper, C.J., Thiel, A., Penker, M., Braito, M., Landon, A.C., Thomsen, J.M., Tucker, C. M., 2018. Incorporating multilevel values into the social-ecological systems framework. Ecol. Soc. 23 (3) https://doi.org/10.5751/ES-10047-230325.

Voß, J.-P., Fischer, C., 2006. In: Micro Cogeneration. Springer-Verlag, Berlin/Heidelberg, pp. 19–47.

Winkel, G., Sotirov, M., 2015. Whose integration is this? European forest policy between the gospel of coordination, institutional competition, and a new spirit of integration: Http://Dx.Doi.Org/10.1068/C1356j, 34(3), 496–514. https://doi.org/10.1068/C1356J.

Wolfslehner, B., Pülzl, H., Kleinschmit, D., Aggestam, F., Winkel, G., Candel, J., Eckerberg, K., Feindt, P., Mcdermott, C., Secco, L., Sotirov, M., Lackner, M., Roux, J.-L. (2020). European forest governance post-2020. diva-portal.org. https://doi.org/10.36333/fs1.