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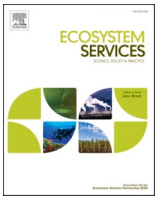

The development of governance innovations for the sustainable provision of forest ecosystem services in Europe: A comparative analysis of four pilot innovation processes

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ABSTRACT

In the past decades, novel governance and management approaches that support the provision of non-marketable Forest Ecosystem Services (FES) have emerged throughout Europe. However, it remains unclear under which circumstances such modes of FES governance develop and which sets of social-ecological parameters, management formats, and interests enable or constrain these processes. In this paper, we aim to shed light on the development processes of such governance innovations. We combine approaches from natural resource governance with insights from innovation studies to identify the close interrelations between designing governance approaches and the inherent innovation dynamics in their development. Empirically, we apply an adapted innovation journey approach to reconstruct the development history of four governance innovations in Europe. We analyse key turning points and crucial influencing factors of the innovation processes, focussing on interests, resources, and values of actors, biophysical and technical conditions of the forest resource systems, institutions and governance arrangements, and features of the innovation management. Our findings show that often individual actors became mainstays of the innovation developments, whereas governmental organisations took up an important role in managing the innovation development process, without being the main change agents. Further, in cases with a reliable legal environment and existing funding schemes innovation development was fostered effectively. While various natural disturbances negatively impacted upon innovation development, most crisis-related interruptions provided an opportunity for radically changing pathways. We conclude that to cope with these uncertain development dynamics, conditions for innovation development need to be created that allow for continuous monitoring and adaptation of innovation processes along their development. For future governance innovation development processes, this calls for the setup of protected spaces that allow for stakeholder participation and open deliberation of interests and expectations regarding FES provisioning as preconditions for governance co-design work based on mutual learning and reflection.

1. Introduction

Forests provide numerous ecosystem goods and services (FES) to society at multiple scales from local to global (García-Nieto et al., 2013; Plieninger et al., 2013; Saarikoski et al., 2018). In this paper, we focus on the European forestry context that is largely characterised by biophysical and institutional heterogeneity and complex horizontal and vertical interplay of policy sectors, instruments, and actors, and which poses

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particular challenges for forest management and the sustainable provision of ecosystem services (Mann et al., 2021). European forests cover about 28 % of the EU land surface (Ceccherini et al., 2020) and the geographical supply of FES is unevenly spread (Orsi et al., 2020). Similarly diverse is the ownership structure. Roughly 40 % are state-owned and 60 % private forest properties, which vary from small family holdings to large-scale public as well as private forests (Eurostat, 2017). As diverse as the forest ecosystems and ownership structures is the range of policies that shape the forestry sector in Europe. Besides dedicated forest policies, sectoral policies from agriculture, energy, nature conservation, climate protection, and rural development play a decisive role for forest management (e.g. Primmer et al., 2021). These sectors and their formal systems of rules are only partially aligned but with rather strong path dependencies that are leading to conflicts in land-use objectives and management decisions for FES provision (Sotirov and Storch, 2018). In particular the provision of FES that have the character of public goods or common-pool resources that are less targeted by markets, requires alternative governance and management approaches for their provision.

In past decades, novel governance and management approaches emerged throughout Europe that support the provision of non-marketable FES, in particular for regulating and cultural services or bundles thereof (Mann et al., 2021). These include changing silvicultural practices to more close-to-nature management (e.g. Bauhus et al., 2017; Puettmann et al., 2009) and the establishment of collaborative forest owner associations (Agrawal et al., 2008) as well as the setup of regional networks, certification systems, and incentive-based mechanisms such as public or private payment schemes for the provision of ecosystem services and habitat banking (Hansjürgens et al., 2016; Wunder et al., 2020). Many of these governance approaches emerged as pilots on a local scale. To date, it remains unclear under which circumstances such novel and innovative modes of FES governance have emerged and developed and which (sets of) social-ecological parameters, management formats, and interests enable or constrain these processes (Mann et al., 2022). A better understanding of the dynamics of FES governance innovations development, and especially of their interactions – or coevolution – with the forestry context is crucial. This would allow for more targeted and better crafted approaches to foster innovation development, and to be prepared for the challenges and pitfalls of such innovation processes (Kuhlmann et al., 2010; Rip, 2012; Voβ et al., 2009).

In this paper, we contribute to narrowing this knowledge gap by gaining a better understanding of the development processes of a selected range of pilot innovations for sustainable governance of FES. Our overarching research question is: What aspects influence the development of FES governance innovations in different contexts? To answer this question we conducted an in-depth analysis of four cases of developing governance innovations for the sustainable provision of FES in Europe. The empirical investigation of these development processes builds on and combines concepts of innovation studies and human-nature interactions. For an analytical reconstruction of the innovation development, we adapted and applied the innovation journey concept, i.e., the understanding of innovations as processes that can be analysed with help of a set of process event categories (Kuhlmann, 2012; Van de Ven et al., 1999). For our analysis of these journeys we draw on a large body of literature addressing human-nature interdependencies, natural resources management, and collective decision-making in complex social-ecological-technical systems (SETS), all of which reveal influences on governance approaches, i.e., their design, development, and working conditions (e.g. Hagedorn et al., 2002; Loft et al., 2015; Ostrom, 2009; Sorge et al., 2022). In our case study analyses, we identify such influencing factors by focusing on key turning points, i.e. events, dynamics, and stakeholder constellations that initiated changes in innovation development.

2. Empirical and analytical approach

We applied a comparative case study approach (Knight, 2001) and compared the governance innovation development for the provision of FES in four selected cases in Europe. We gathered qualitative data through document analysis and semi-structured expert interviews. In our analysis, we followed an adapted version of the innovation journey concept for reconstructing the emergence and innovation development over time (Van de Ven et al., 1999) and identified turning points and key influences that shaped the governance innovation development via a thematic analysis (Fereday and Muir-Cochrane, 2006).

2.1. Conceptual foundation

Innovations are often initiated by a group of actors that steer their development. However, innovations should not be regarded as a straight-forward, linear process that can be programmed or would lead to a precisely defined result (Kuhlmann et al., 2010). Innovations can rather be described as iterative social processes with outcomes very much dependent upon the context they develop in. This contextual process dependence was first captured in the notion of an 'innovation journey' in research on corporate innovations (Kuhlmann, 2012; Van de Ven et al., 1999). Innovation scholars subsequently incorporated innovation's socio-technical context (Rip, 2012) and socio-cultural, economic, and political landscape developments (Geels, 2002; Geels and Schot, 2007). In his adaptation of the concept, Voβ (2007: 5) emphasized the "duality of social process as captured in pairs of terms like design and dynamics, management and politics or planning and (co-)evolution". Innovations, thus, respond to and at the same time co-produce their context conditions. Following Van de Ven et al. (1999: 212-213), we suggest to imagine innovation as a journey into uncharted waters, in which innovation managers "are to go with the flow – although we can learn to manoeuvre the innovation journey, we cannot control it".

For gaining an understanding of the iterative process of governance innovation development in our case study analysis, we draw on this conceptual foundation in innovation studies. We combined Van de Ven et al. (1999) twelve original process events with specific categories from Voβ (2007), adjusted definitions of the existing categories, and introduced additional categories where necessary. The application of these categories to our case studies allowed us to reconstruct the governance innovation development as innovation journeys, and to identify their patterns and typical components (see Supplementary Material for details). For the analysis of influencing factors that shaped innovation development we zoomed into key turning points (KTPs) of the innovation journeys, i.e. events, dynamics, and stakeholder constellations that reflect changes in innovation development.

Our analysis of factors that foster or hinder the emergence and development of the governance innovations is structured along four dimensions that capture innovation management and the SETS context, in which the innovation develops:

- We review the *innovation management* with a particular focus on the key modes of social steering supported by the project-driven development of the governance innovation. Here, we look at different forms and processes of (joint) decision-making, implementation, monitoring, and sanctioning (Hagedorn, 2008). This includes forms of self-organised coordination such as participatory processes or workshops, but also hierarchical forms of coordination such as top-down influenced planning decisions by the case-related Innovation Region teams (Bussola et al., 2021; Mann et al., 2021). This type of collaboration involved a tandem between a regional practice partner responsible for steering innovation development and a partner from an academic organisation.
- We highlight the interests, resources, and values of *key actors* that are directly or indirectly involved in the development of the respective governance innovation and those actors potentially affected by the

innovation. This includes providers and beneficiaries of FES like forest managers and tourists, but also those involved in the development of the governance innovation such as policy makers, public administrations, scientists, and financial organisations (Hauck et al., 2013). Those actors need to be understood as embedded into a dynamic system of interdependent relationships, deeply rooted in the local situations, and often forming a 'network of mutual dependency' (Zimmermann and Maennling, 2007). However, their influence on decisions regarding the development of the governance innovations and the degree of affectedness from these decisions varies substantially.

- We assess the *institutions and governance arrangements* that affect the development of the governance innovation. Understood as formal or informal, yet regularised rules that structure human interactions, constraining, and facilitating them (North, 1991), institutions are guiding resource-use decisions. Here, governance arrangements encompass the "process by which the repertoire of rules, norms, and strategies that guide behaviour within a given realm of policy interactions are formed, applied, interpreted, and reformed" (McGinnis, 2011: 171). Both institutions and governance arrangements are central mediating factors between human choices or activities and the broader socio-economic, technological, political, and cultural context. We are interested in property rights as they define the access to as well as use and control of forest-related resources (Ribot and Peluso, 2003), in legal frameworks and other policy instruments that coordinate actor specific behaviour and actions (Williamson, 2005), but also in the 'internal' rules, i.e., the structural components of the governance innovation itself (e.g. rules for compensation).
- We capture the *key biophysical and technical conditions* of the forest resource system that affect the development of the governance innovation. This includes underlying environmental processes and functions, management forms and composition of the forest, natural hazards but also characteristics of the biogeographical landscape. Further, relevant features of the technical infrastructure like sawmills and forest roads are directly linked to the provision of the FES (Agrawal, 2002). Thus, the specific properties of the SETS under scrutiny not only shape FES provisioning (Ostrom, 2007) but also the interdependence between actors (Paavola and Adger, 2005).

2.2. Case selection

To understand particular dynamics and its causes in the development of governance innovations, we selected four cases that were part of an EU H2020 Innovation Action (2017–2020) (Table 1). The project's objective was to study and assist in the development of governance innovations that incentivise the provision of FES as bundles in a context-sensitive and sustainable way. In each case, the innovation development process was driven and managed by the IR team. These IR teams consisted of members of a local organisation for the promotion of innovation, an administration, or a project executing agency as well as employees of a university within that region. The former were responsible for managing the project and maintaining relations with the stakeholders while the latter were responsible for data collection in the run-up and documentation of the process. The cases differ in social-ecological-technical forest and forestry conditions. They represent different biogeographical regions of European forests, and differ in targeted FES types, forms of forest management and governance, and business environments. Being closely shaped by the regional settings, they serve as loci for learning for particular types of governance innovations. Two innovation cases feature an incentive-based approach to FES governance and two cases focused on a network approach.

2.2.1. Governance innovation 1: forest pasture system management, Italy

Developing a network approach that links private business to public entities and public funding in order to maintain a balanced provision of ecosystem services in mountain forests and pastures (goat, sheep, cattle) was the main objective in the IR Trentino. The idea of forest-pasture management emerged with the introduction of forest planning in the 1950s. In the 1980s, the focus of the management practices broadened: while previous emphasis rested on timber production, other FES, such as soil protection or recreation had become more important. Open areas and wooded pastures were considered as crucial and integrated elements of the forest ecosystem. In 2014, the local Autonomous Province of Trento office (PAT) conducted a public–private demonstration project aiming at landscape restoration through agri-silviculture. A further project restoring a larger area of meadows and pastures was carried out between 2015 and 2018. For the EU H2020 project, the University of Trento and PAT further developed the idea of establishing a permanent public–private network for pasture management by creating an organizational basis and by generating permanent funding. The idea was to solve management issues, to foster a more active role of all participants, and to introduce new management activities such as cutting of newly formed woods and restoring turf grass.

2.2.2. Governance innovation 2: value chains and network for forests and wood, Austria

In the IR Eisenwurzen, efforts towards a sustainable regional development with emphasis on stakeholder participation, nature conservation, and value creation date back to the 1990s. Between 2011 and 2013, the regional practice partner STUDIA (Study Group for International Analysis) coordinated an EU-funded INTERREG project. Yet, the regional stakeholder network along the forest-wood value chain remained rather fragmented. The EU H2020 project was seen as an opportunity to reinvigorate collaboration. The IR team aimed at uncovering and promoting stakeholders' expressed, but often unimplemented, innovation ideas and activities to enable bottom-up innovation. Based on the stakeholders' preferences, the IR team decided to pursue three governance innovation ideas in parallel: Furniture, design and region; Mobile wooden tiny-houses and tourism; and Experiencing forest and wood. When further exploring these options most stakeholders were keen on connecting and pursuing two or more of those ideas. To allow for integrating these innovation ideas as well as facilitating stakeholder exchange in general, the idea of establishing an 'innovation platform forest-wood' as an organisational construct was pursued, too.

2.2.3. Governance innovation 3: Habitat Bank of Finland, Finland

The idea of using economic instruments for steering biodiversity compensation had arrived in Finnish forest governance already in the early 2000s. From 2002 onwards, the national scheme "METSO" provided Finnish landowners with monetary payments for voluntarily implementing biodiversity conservation measures in forest areas–a classic Payments for Ecosystem Services scheme. In the course of the EU H2020 project, the Finnish Environment Institute (SYKE) aimed to build on existing stakeholder networks and activities to test the feasibility of the idea of a "Habitat Bank of Finland". As another market-like conservation policy instrument, a habitat bank aims to facilitate private sector compensation for the ecological harm private sector's activities cause. In 2015, SYKE and the University of Helsinki had successfully enrolled the idea of a Habitat Bank of Finland for ecological compensation in a research impact competition called the "Helsinki Challenge". SYKE intensified its work on a voluntary biodiversity compensation scheme and acquired funds for developing the Habitat Bank of Finland concept in the ongoing project "EKOTEKO". In the EU H2020 project, SYKE and the practice partner Finnish Forest Centre (FFC) were aiming to operationalise and pilot the Habitat Bank of Finland, focusing on connecting potential actors on the demand side with those that were willing to provide compensation sites.

2.2.4. Governance innovation 4: Forest Share, Germany

The Forest Share (German: "Waldaktie") had initially been developed in 2007/08 by the Ministry for Agriculture, Environment and

Table 1
Overview of selected governance innovations.

Governance innovation	Governance innovation type	Location	Governance level	Vegetation	Forest ecosystem services	Partners in the IR management	Actors involved in innovation development
Forest Pasture System Management, Italy	Network approach and new partner alliance: Forest pasture integrated management system	Autonomous Province of Trento – Primiero, Italy. Border between Trentino and the Province of Belluno (Veneto). Size of 413 km^2. The area is surrounded by three mountain groups: the Lagorai to the west, the Vette Feltrine to the south, and the Pale di San Martino to the north.	Regional to federal state	The vegetation reflects both the characteristics of the physical environment such as climate, morphology of the slopes, soils, and the action of man, which has significantly modified the composition and structure of spontaneous vegetation.	Water regulation, protection from natural hazards, recreation and nature-based tourism	Autonomous Province of Trento office, Forest and Fauna Service (PAT) University of Trento (UNITN)	Alpine Club; Breeder Organisation; European Union Regional Development Fund; Forest District; Freelance; Forester; Forest Owner; Hunters Association; Hotel Owner; Municipality; Nature Conservationists; Forest Service; Private Farmers; Private Landowners; Sawmill Operator; Tourist Board;
Value Chains and Network for Forests and Wood, Austria	Network approach and new stakeholder alliance: Public-private partnership	Eisenwurzen is a mountainous border area of the provinces of Lower and Upper Austria and Styria, between the northern part of Kalkalpen and the northern Alpine Foreland. There are two National Parks, Kalkalpen and Gesäuse.	Regional to federal state	The sparsely populated region features a traditional cultural landscape dominated by agriculture (arable and pastures) and forestry, with a forest cover ratio of partly over 80 % in some of the 91 municipalities. In the remote areas of the mountain valleys, pastures are frequently not mowed anymore, which leads to an overgrowth of bushes and forests. Forest plots are often integrated into small and medium-sized farms, and are likewise managed by small-scale private farmers (more than 6,300 agricultural & forestry holdings). The national parks cover remote, rocky and forested areas with restrictions in use.	Cultural, biodiversity, timber	Study Group for International Analysis (STUDIA) University of Innsbruck (UIBK)	Working group wood from the community of Sauwald, Forest related small-medium enterprises; Program funded by the European Regional Development Fund; Long-Term Social-Ecological Research platform Eisenwurzen; Lumacon Holztechnologie GmbH; Institute for Social Ecology; Wood design training course "Überholz" at the University of Art and Design Linz;
Habitat Bank of Finland, Finland	Payments scheme and compensation: Biodiversity payments and habitat banking	The case study idea and its early development covers Finland as a whole.	Regional to national	Finland is located in the north-eastern corner of Europe, with 2/3 of its land-surface covered with forests. These forests host a great share of Finland's biodiversity, and also a majority of the country' endangered species dwell in forests. Apart from Lapland up North, most of Finland's forests are commercially managed. All managed forests serve multiple functions (providing timber, non-timber- forest products, recreation and regulating services).	Biodiversity, carbon, timber	Finnish Forest Centre (FFC) The Finnish Environment Institute (SYKE)	EKOTEKO Habitaattipankki tutkimuskonsortio (Habitat Bank research consortium); FIBS Finnish organization; promoting sustainable business; METSO Forest Biodiversity Programme for Southern Finland;
Forest Share, Germany	Payments scheme and compensation: Voluntary carbon markets and forest trusts	Mecklenburg-Vorpommern, is federal state in the north-east of Germany.	Federal state	Mecklenburg-Vorpommern has 24 % forest cover. 39 % of the forest is privately owned, 46 % by the federal state, and 10 % by the communes. The climate forests are located in different parts of Mecklenburg-Vorpommern. Presently, overall 18 climate forests exist across all parts of the federal state. They cover an area of 120 ha.	Timber, non-timber products, carbon	The Academy for Sustainable Development Mecklenburg-Vorpommern (ANE) Leibniz Centre for Agricultural Landscape Research (ZALF)	Environmental Non-Governmental Organisation; Fridays for Future; Green Party; Ministry for Agriculture, Environment and Consumer Protection; Westmecklenburgische Energieversorgung AG (WEMAG)

Consumer Protection of the German federal state of Mecklenburg-Western Pomerania and implemented in collaboration with the State Tourism Agency. It was a voluntary payment scheme that financed the planting and maintenance of forests to compensate for greenhouse gas emissions. The initial idea was that tourists could 'compensate' the emissions they caused during their holidays in the federal state. After its initial success, the share sales stagnated after 2015. It had become difficult to find new areas for reforestation, and, in addition, the share price no longer reflected the costs of forest planting activities. Aspects like the payment method, logistics, and marketing were also in need of an update. In addition, the State Tourism Agency, initially responsible for selling the shares, wanted to pass on this task to another organisation. Thus, a re-invention of the Forest Share was considered to be necessary. The Academy for Sustainable Development Mecklenburg-Western Pomerania (ANE) became the new forest share manager, and aimed at developing a 'Forest Share 2.0' during the course of the EU H2020 project.

2.3. Data collection

The data for reconstructing the innovation developments was collected in four phases. In *phase 1*, the authors reviewed all reports and other forms of documentation of the innovation processes that had been produced in the course of the EU H2020 project from October 2017 until March 2020. This included workshop reports, project memos, and audio recordings of project meetings and transcribed interviews with practice and scientific partners (see https://innoforest.eu/enabling-innovation/; Sattler, 2022; Sorge et al., 2022). In *phase 2*, the authors conducted one open narrative group interview with each of the four IR teams who had facilitated the innovation development in the region. In this first interview, IR teams were asked to openly reflect on the innovation development process, its main events and main challenges. Due to the Europe-wide Covid-19 lockdown measures, interviews were carried out via a video conference platform. Based on the empirical information gathered, in *phase 3*, the authors developed a preliminary chronology and categorization of relevant activities and events, and asked IR teams to edit, complement, and validate the resulting documentation. Furthermore, IR teams were asked to highlight what they considered as being key activities and events. The resulting changes were discussed with IR teams in another online meeting. Finally, *in phase 4*, the authors condensed this compilation into a process analysis, the 'innovation journey' of each case, which was then, again, validated by the respective IR team. In addition, each process analysis was visualized in a figure, which resulted in a continuous alignment and reflection of the path development and the degree of innovation maturation in the respective stages.

2.4. Data analysis

The analysis of the governance innovation development process is based on the reconstructed innovation journey of each case study (see SM Sections 1 and 2 for details about the innovation journey concept, SM Section 3 for details of its adaptation, and SM Section 4 for the innovation journey reconstruction for each case). Along the four analytic dimensions of the SETS (outlined in Section 2.1), the analysis focuses on factors that foster or hinder innovation development. The entry points for the analysis are key turning points of innovation development. These turning points serve as observable manifestations of change. As 'key turning points', the authors define events during the progression phase of the innovation development (i.e. the formal innovation project work within the EU H2020 project) that significantly influenced the degree of innovation maturation and the path development of the innovation. As an event, the authors consider both, single events but also multiple, yet closely linked events, such as larger stakeholder workshops or meetings of the IR teams. The effects of these events did not always manifest immediately after the event took place. Rather, some events contributed to a change in path development at a much later stage in the innovation journey.

For the identification of the turning points, each author independently marked all changes in the maturation of the innovation development as indicated in each of the innovation journeys. Each author then highlighted three to five turning points he/she considered to have the most influence on path development. Finally, the team of authors jointly discussed the selected turning points – in case individual judgements differed – until consensus was reached. A similar process was chosen for the assessment of the factors that shaped governance innovation development. In a first step, each author individually coded the key turning points of each case using the four analytic dimensions of the SETS. In addition, each author weighted the manifestation of the dimensions in each key turning point on a three-level scale (−/+/++). The individual results were then compared and discussed within the author team until consensus was reached to ensure consistent and intersubjectively reproducible data.

3. Factors influencing innovation development

In the following, for each case, we present key turning points in the development of the assessed governance innovations (Figs. 1–4) and the manifestation of the SETS dimensions in these key turning points (Tables 2–5), i.e. which features of the innovation management, actors, institutions and governance arrangements, and biophysical and technical conditions have had an impact in these turning points and on the subsequent innovation journey (see SM Section 4 for details of the innovation development in each case).

3.1. Forest pasture system management, Italy

3.1.1. 1st key turning point: adapting to the impacts of the Vaia windstorm

In 2018, the Vaia windstorm hit north-eastern Italy and parts of Austria. In the IR Trentino, about 18,300 trees were uprooted and more than 3 Mio. m^3 of timber were windthrown (Chirici et al., 2019; Giannetti et al., 2021). The storm's impact on the Trentino forest triggered adaptations of the initial innovation development workshop strategy, which had centred on four scenarios: 1) 'pure' pasture and forest management; 2) funding FES provisioning via tourism; 3) creating an association of forest owners; 4) establishing a cooperative of sawmills. In particular, it was difficult to keep up the initial stakeholder constellation: Previously involved woodsmen and sawmill operators were now occupied with removing the storm damages. At the same time, the severe windthrow damage and land-cover transformation presented a strong motivation for policy-makers and agriculture-related stakeholders to become involved: They saw an opportunity to promote the maintenance of open landscapes, with pasture restoration and agroforestry ecosystems as specific measures. This new actor constellation and the changed thematic interests were reflected in an exploratory workshop in January 2019 and in the first stakeholder workshop in May 2019. Thus, a mix of drastic changes in the biophysical conditions, a change in actor constellations, and a resulting decision of the IR team led to this first turning point in innovation development.

3.1.2. 2nd key turning point: dealing with the specification of the Province Forest and Mountain Plan

In autumn 2019, the Province's Forest and Mountain Plan (FMP), was further specified now exhibiting many objectives that were similar to the aims of the governance innovation development, such as the clearing and recovery of storm-damaged areas and the restoration of historic pastures. The perspective of a larger regional scale–now covering the entire Trentino Province, not only the forest district of Primiero–and a longer time horizon with financial compensation opportunities provided by the FMP resulted in a decrease of stakeholder participation in the governance innovation development. Thus, a change in the institutional and governance arrangements in the form of the

specification of a formal planning instrument, i.e., the FMP, had a further negative impact on the motivation of key actors like woodsmen and sawmill operators to actively engage in the further development of the governance innovation.

3.1.3. 3rd key turning point: accounting for changes in actor constellations and objectives

In December 2019, as a long-term consequence of the previous two turning points, the IR team decided to discard those innovation development scenarios that depended on participation of woodsmen and sawmill operators. These actors continued to struggle with the aftermath of the Vaia storm and were therefore unable to participate in upcoming workshops. Instead, the focus was put on the restoration of pastures and meadows and the development of local tourism. The IR team took the decision to only pursue scenarios for the innovation development that reflected the new biophysical reality and were carried by the actors that were able to engage. Thus, the persistent change in the actor constellation, caused by the Vaia storm a year before, resulted in a significant strategic decision at the innovation management level further stimulating the innovation development in preparation of the second stakeholder workshop in December 2019.

3.1.4. 4th key turning point: halting innovation alignment during the Covid-19 outbreak

The outbreak of the Covid-19 pandemic in February 2020 stalled various forestry activities, the development of the FMP, and the IR team's efforts to improve connectivity between innovation development and FMP. Northern Italy was hit particularly hard by the pandemic, which triggered substantial legal restrictions such as curfews and lockdowns that prevented meetings. As a result, all networking activities were cancelled by the IR team in response to the change in biophysical conditions and the ensuing modifications in the formal and informal institutions and governance arrangements.

Table 2
Elements of the SETS that foster KTPs.

	KTP-1	KTP-2	KTP-3	KTP-4
Innovation management	+	+	++	+
Actors	+	+	+	−
Institutions and governance arrangements	−	++	−	+
Biophysical and technical conditions	++	−	−	++

The four cross-cutting dimensions of the SETS were reviewed for each KTP and weighted relative to their effect on a three-level scale (−/+/++). This process was carried out through iterative and constant comparisons between the author team to ensure consistent and intersubjectively reproducible data.

3.2. Value chains and network for forests and wood, Austria

3.2.1. 1st key turning point: broadening the range of potential governance innovations

Soon after the start of the EU H2020 project, the IR team conducted stakeholder interviews to actively explore stakeholders' interests, visions, and ideas and to put the preliminary modular furniture option to a test. Content-wise, this resulted in a broadening of the number and range of governance innovations to be pursued. Regarding the format, this led to the decision to conduct thematic focus groups before organising the first stakeholder workshop. The results of the focus groups confirmed that all three innovation ideas should be further pursued and were in line with the stakeholders' interests and preferences. Thus, the interrelated key dimensions are innovation management and actors.

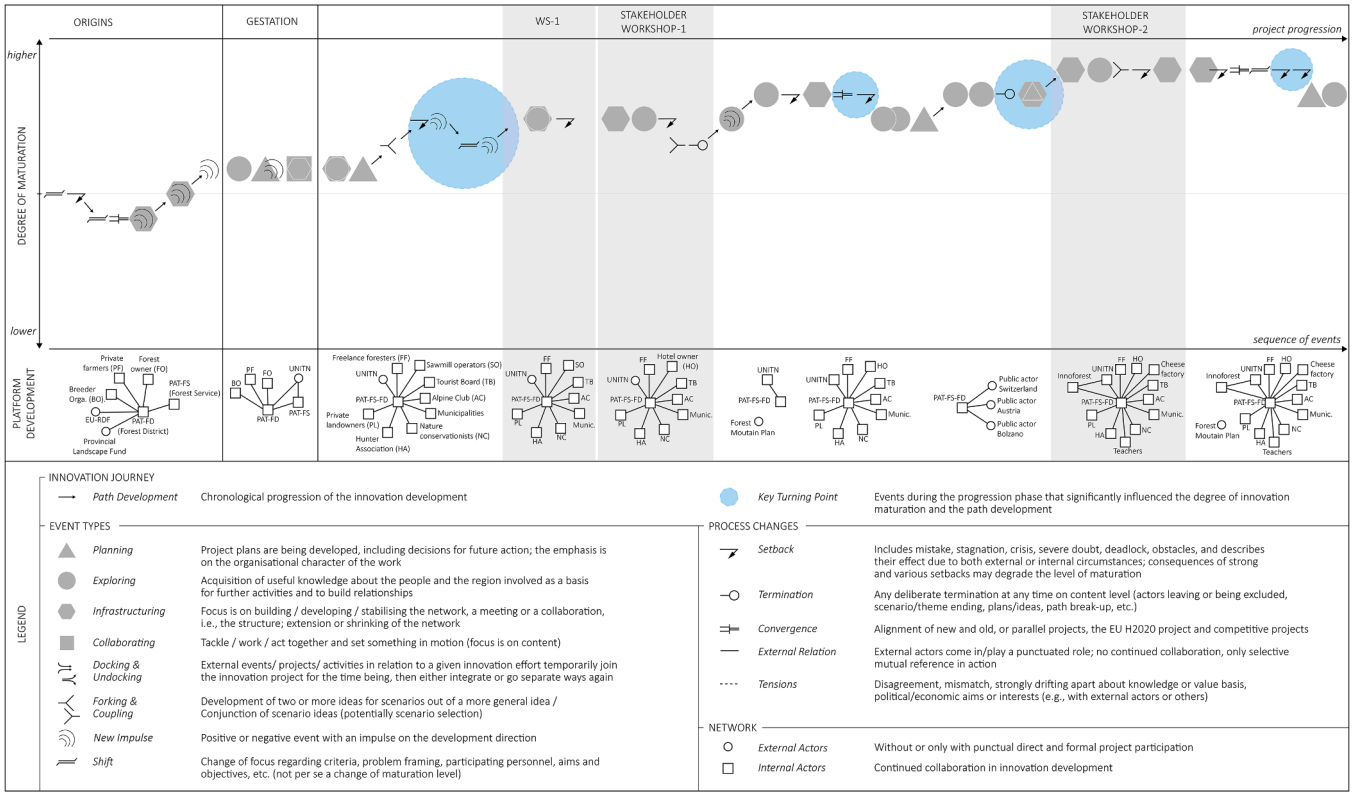

Fig. 1. Turning points in innovation development Forest Pasture System Management, Italy. The case-specific KTPs in innovation development were mapped over the course of the innovation journey, which identifies a set of structural events, process changes and action types starting from the origins of the innovation work to the end of the project. In addition, the degree of maturation as well as the relationships between external and internal key actors for innovation development can be derived for the individual KTPs (see SM Section 2 for details on the method and SM Section 4.1 for the Italian case).

3.2.2. 2nd key turning point: adding a focus on platform and network building

Due to strong networking efforts of STUDIA, the first stakeholder workshop brought together a broad range of stakeholders featuring input presentations regarding the three innovation ideas and extensive group work. Most stakeholders showed an interest in at least two of the discussed innovation ideas and in connecting them. The workshop design created group spirit and enthusiasm, and the stakeholders emphasized the importance of a common platform for network building and creating synergies between different forest-related innovative activities in the region.

In the aftermath, the 'innovation platform forest-wood' was introduced as another, fourth, innovation idea by the IR team. To some extent, the large size of the Eisenwurzen region, where many stakeholders live far from each other, has also highlighted the need for an organisational structure in which stakeholders interact on a regular basis. Thus, apart from key decisions taken by the innovation management, biophysical aspects as well as actors' preferences were decisive here.

3.2.3. 3rd key turning point: facing new obstacles and dispersed actors' interests

Despite focusing on the activation of actors, the second stakeholder workshop did not create substantial progress with regard to concretizing any of the innovation ideas. The stakeholders at the workshop were concerned about anticipated bureaucratic, administrative, and legal obstacles that might impede the implementation of the three thematic innovation ideas and were sceptical with respect to the ideas' economic viability, in particular if using regional wood resources. Further, forestry-related stakeholders pointed out they did not feel sufficiently 'connected' to the innovation ideas and that it would take a long time until potential benefits affected their businesses. As the workshop took place in the neighbouring valley, there was also a high number of new stakeholders adding to the heterogeneity of stakeholders' interests. Thus, a broad range of dispersed actors' preferences and concerns as well as aspects related to the institutional and governance arrangements mainly affected this key turning point.

3.2.4. 4th key turning point: lacking a common vision and a leading actor

Due to the little progress made at and after the second stakeholder workshop, the IR team formed a 'task force' of particularly motivated stakeholders to foster the development of the three thematic innovation ideas in smaller groups. However, since the first task force meeting failed to identify 'innovation idea champions', the IR team decided to focus on the development of the innovation platform as the key topic of the third stakeholder workshop. Here, the stakeholders nevertheless could not agree on a common vision or objective of such an innovation platform. Further, no individual stakeholder felt sufficiently motivated or able to take the lead in organising the subsequent platform building activities, which was partly due to the lack of established (in-)formal

Table 3
Elements of the SETS that foster KTPs.

	KTP-1	KTP-2	KTP-3	KTP-4
Innovation management	++	++	+	+
Actors	+	+	++	+
Institutions and governance arrangements	−	−	+	+
Biophysical and technical conditions	−	+	−	+

The four cross-cutting dimensions of the SETS were reviewed for each KTP and weighted relative to their effect on a three-level scale (−/+/++). This process was carried out through iterative and constant comparisons between the author team to ensure consistent and intersubjectively reproducible data.

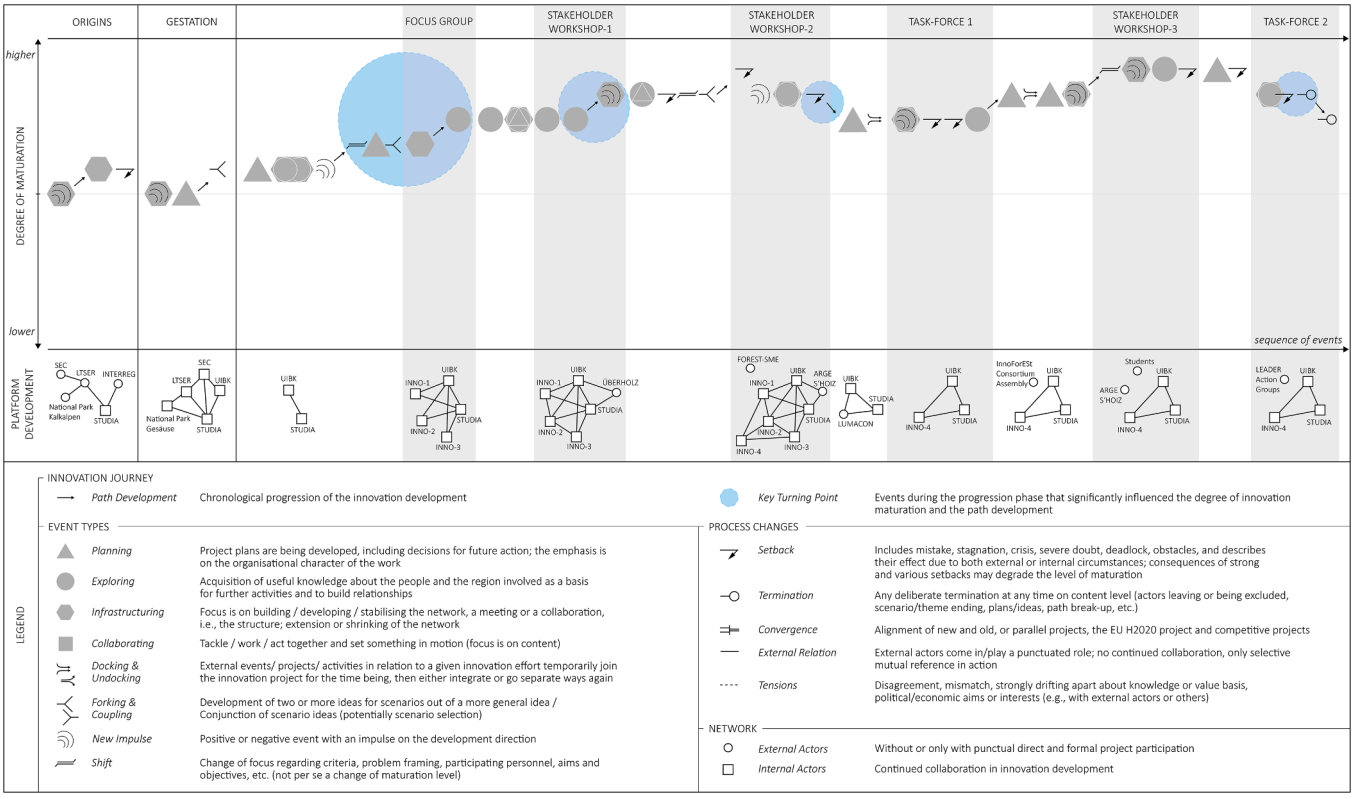

Fig. 2. Turning points in innovation development Value Chains and Network for Forests and Wood, Austria. The case-specific KTPs in innovation development were mapped over the course of the innovation journey, which identifies a set of structural events, process changes and action types starting from the origins of the innovation work to the end of the project. In addition, the degree of maturation as well as the relationships between external and internal key actors for innovation development can be derived for the individual KTPs (see SM Section 2 for details on the method and SM Section 4.2 for the Austrian case).

structures of region-wide cooperation and communication. This reluctance to take the lead was confirmed at a second task force meeting that was organised as hybrid event in June 2020, although stakeholders managed to agree on general objectives of such a platform. The Covid-19 pandemic and resulting legal restrictions also prevented face-to-face contacts from March 2020 onwards, while many actors proceeded with their own projects during this phase, highlighting the key influence of biophysical conditions, actors, and innovation management.

3.3. Habitat Bank of Finland, Finland

3.3.1. 1st Key Turning Point: Focussing on voluntary contract schemes

Stakeholder interviews at the beginning of the EU H2020 project had resulted in three initial ideas for the development of the governance innovation under the already existing umbrella project for compensation, the Habitat Bank of Finland: An authority-driven mechanism, a voluntary contract scheme, and a nature value bank. Discussions at the first stakeholder workshop highlighted the need for a very specific pilot project as a showcase for any of the innovation ideas and for developing a more detailed remuneration mechanism. Since this was too difficult to achieve for all three innovation ideas, the IR team decided to continue only with the voluntary contract scheme. Thus, a combination of newly revealed actors' preferences, difficulties to concretize institutional and governance arrangements related to the remuneration mechanism, and innovation management decisions triggered this key turning point.

3.3.2. 2nd key turning point: searching for private actors with sufficient interest in the scheme

An excursion to Central Finland and telephone interviews with private forest owners carried out by the IR team did not result in finding private landowners willing to provide their land for compensation measures. This was mainly because for the forest owners the exact remuneration mechanism remained unclear. Further, with compensation being voluntary for private project developers, the incentive for them to participate in such a scheme was low. Thus, the IR team decided to put more emphasis on involving potential contracting parties, i.e., forest landowners with potential compensation sites and businesses from construction and gravel industry, who could use compensation as Corporate Social Responsibility measures, when preparing the second stakeholder workshop. A series of innovation management activities and continued challenges with institutional and governance arrangements and decisions, but in particular the persistence and diversity of actors' preferences, contributed to this key turning point.

3.3.3. 3rd key turning point: turning to public actors with potential pilot sites

Despite a constructive atmosphere during the second workshop, two main problems remained unsolved: The matching of ecologically valuable sites with those that are destroyed, and the calculation of offsetting costs and thus remuneration levels. Further, in the aftermath of the workshop several businesses which had been interested in compensation before became hesitant as they did not want to be the first companies admitting their responsibility for biodiversity loss. Those firms also indicated that they preferred compensating on their own forest properties rather than on land owned by a third party.

The complexity and difficulties around how to involve private stakeholders, site matching, and the calculation of the offset costs remained until the beginning of 2020. This kept forest owners and businesses from committing to contractual compensation agreements. The IR team subsequently decided to focus on public actors, in particular municipalities, at least as a compensating party. The municipality of Lahti turned out to be interested in initiating a pilot through which they would compensate for the construction of a large residential building. As green capital of Europe 2021, Lahti was particularly interested in a successful implementation, however, obstacles remained: The municipality preferred to compensate on their own land, and the ecological damage of the residential building was supposed to be compensated on a single site. Despite a halt in negotiations between the IR team and the

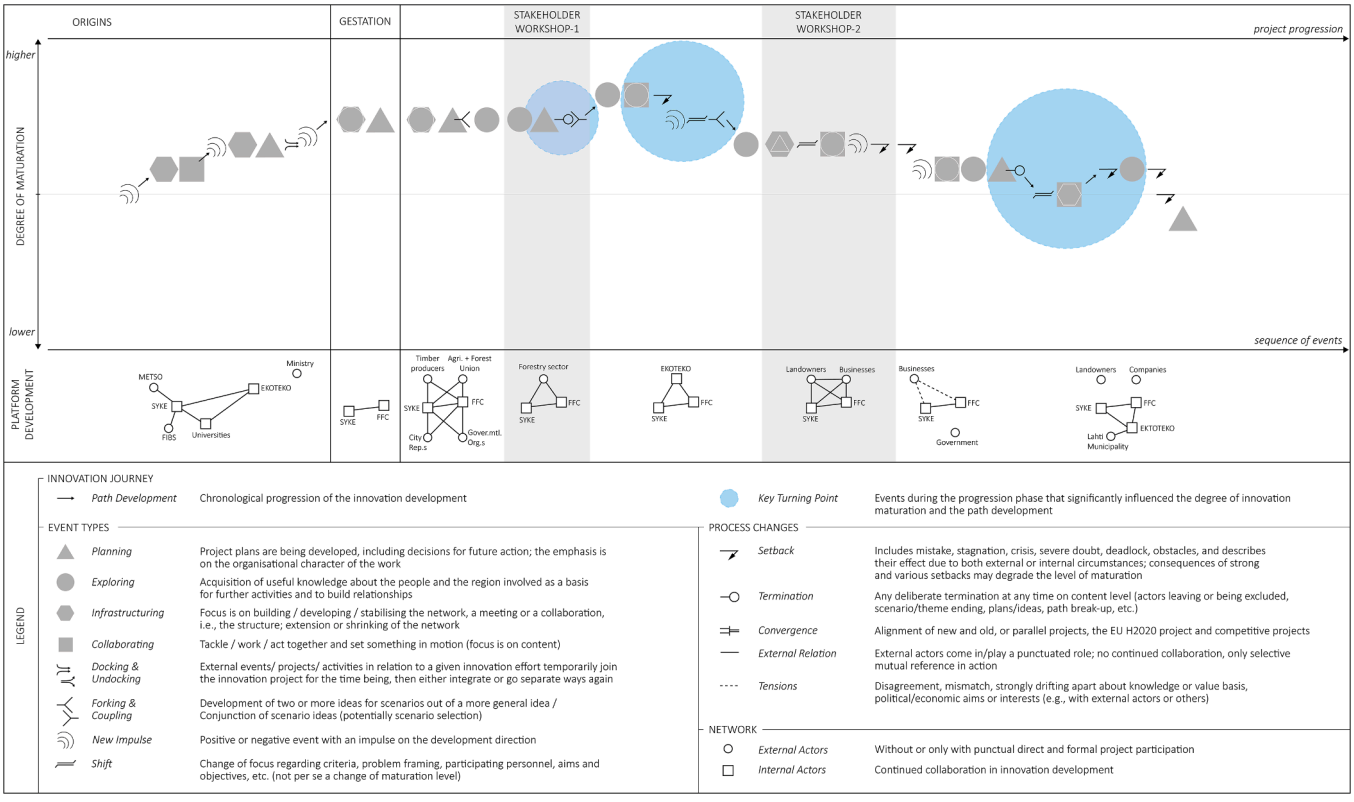

Fig. 3. Turning points in innovation development Habitat Bank of Finland, Finland.

Table 4
Elements of the SETS that foster KTPs.

	KTP-1	KTP-2	KTP-3
Innovation management	+	+	++
Actors	+	++	++
Institutions and governance arrangements	+	−	+
Biophysical and technical conditions	−	+	−

The four cross-cutting dimensions of the SETS were reviewed for each KTP and weighted relative to their effect on a three-level scale (−/+/++). This process was carried out through iterative and constant comparisons between the author team to ensure consistent and intersubjectively reproducible data.

Lahti municipality due to the Covid-19 pandemic, the municipality started looking for a suitable compensation site. Thus, a strong (public) actor entering the innovation development, respective innovation management activities, yet also old and new problems related to the institutional and governance arrangements were crucial for this key turning point.

The case-specific KTPs in innovation development were mapped over the course of the innovation journey, which identifies a set of structural events, process changes and action types starting from the origins of the innovation work to the end of the project. In addition, the degree of maturation as well as the relationships between external and internal key actors for innovation development can be derived for the individual KTPs (see SM Section 2 for details on the method and SM Section 4.3 for the Finnish case).

3.4. Forest share, Germany

3.4.1. 1st key turning point: experiencing obstacles for innovation reconfiguration

After initializing a process–at the beginning of the EU H2020 project–for reconfiguring the existing and ongoing Forest Share innovation, which demonstrated a high level of maturation and a strong stakeholder network, the innovation development towards a "Forest Share 2.0" stagnated. First, the State Forestry Management Agency responsible for the Forest Share lacked rights to acquire additional land for forest replanting. Second, the State Tourism Agency as an essential partner in the Forest Share suffered budget cuts. Third, a local energy provider (WEMAG) had become the largest buyer of Forest Shares. This meant that the Forest Share's initial focus on offsetting tourist's carbon emissions and connecting it to the landscape by participating in-or at least financially contributing to-actual tree planting activities seemed to be replaced by an ordinary voluntary carbon market offset scheme. Further, the State Tourism Agency did not want to get associated with the new main shareholder WEMAG, who was criticized for using the Forest Share scheme for 'greenwashing'. In this way, the actors' increasingly diverging interests, challenges related to the institutional and governance arrangements, and the lack of a strong innovation management contributed to the first key turning point.

3.4.2. 2nd key turning point: recognising innovation potential

Triggered by the substantial and diverse challenges for reconfiguring the 'old' Forest Share, the IR team initiated a discussion about the strengths, weaknesses, opportunities, and threats of the business model at the first stakeholder workshop. The co-produced outcomes substantially strengthened the confidence of the involved actors–the State Ministry for Agriculture and Environment, the State Tourism Agency, and the State Forestry Management Agency–in further pursuing the reconfiguration of the existing Forest Share model and to constructively deal with the previously identified challenges. Thus, a mix of realigned actors' interests and innovation management decisions triggered this key turning point.

3.4.3. 3rd key turning point: changing the price mechanism and improving educational activities

Inspired by the discussions at the second stakeholder workshop and encouraged by the increasing public discourse about the consequences

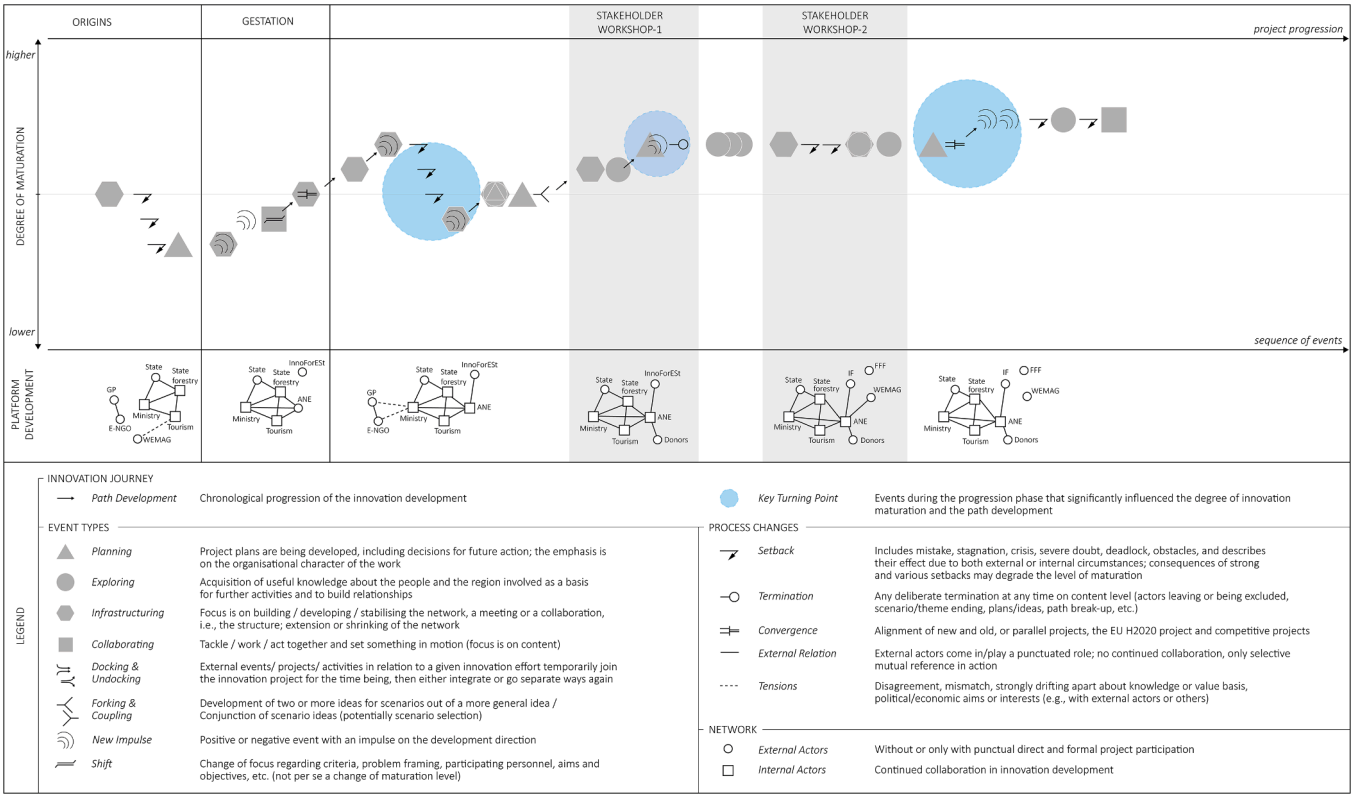

Fig. 4. Turning points in the innovation development of Forest Share, Germany.

Table 5
Elements of the SETS that foster KTPs.

	KTP-1	KTP-2	KTP-3
Innovation management	−	+	+
Actors	+	+	++
Institutional and governance arrangements	++	−	+
Biophysical and technical conditions	−	−	+

The four cross-cutting dimensions of the SETS were reviewed for each KTP and weighted relative to their effect on a three-level scale (−/+/++). This process was carried out through iterative and constant comparisons between the author team to ensure consistent and intersubjectively reproducible data.

of climate change, the three main actors decided to increase the price per share to better reflect the actual costs of compensating afforestation measures and the marketing of the Forest Shares, which had previously been subsidized by the State Forestry Management Agency. Further, the main actors also agreed to increase educational activities highlighting the benefits of FES, for example, through organized tours, display boards, and events. At that time, the perceived abstract impacts of global climate change began to materialize on a local scale: Regional droughts and forest fires were increasingly experienced by society and represented in public discourses. This situation reassured the involved actors in their envisioned content adjustments to the Forest Share innovation. Thus, a combination of factors related to (main) actors' interests and decisions, innovation management activities, and the institutional and governance arrangements contributed to this key turning point.

The case-specific KTPs in innovation development were mapped over the course of the innovation journey, which identifies a set of structural events, process changes and action types starting from the origins of the innovation work to the end of the project. In addition, the degree of maturation as well as the relationships between external and internal key actors for innovation development can be derived for the individual KTPs (see SM Section 2 for details on the method and SM Section 4.4 for the German case).

4. Synthesis and cross-case comparison

In the following sub-sections, we present a synthesis and a cross-case comparison of our empirical analysis of the governance innovation journeys along our four analytic dimensions. Further, we highlight the importance of considering initial starting conditions of each innovation.

4.1. Innovation management

The innovation development process managed by IR teams required facilitating science and practice partners, regional stakeholders, and the EU H2020 project partners. The management of an unfolding variety of sometimes contradicting interests of the different stakeholders posed a major challenge. However, for innovation development it was essential that stakeholders became attracted by and committed to the innovation idea. This required a strong actor network development. We observed different intensities of facilitating stakeholder engagement. In the Austrian case, the practice partner STUDIA invested a lot of time in approaching potential stakeholders, and interviews conducted as part of a stakeholder analysis helped to identify and engage new stakeholders. The intensity of the workshops, the long-term mobilization of the stakeholders, and the formation of a stakeholder task force suggest a particularly high level of management organization. In the Italian and German cases, after an initializing phase of existing stakeholder networks the drive for network expansion stalled quickly. What followed can be regarded as 'network maintenance work' rather than an effort to further engage new actors or establish a new network. Overall, we find that self-organization was central to innovation development, but manifested itself mostly in the Austrian case. In the other cases, as a consequence of not clearly defined or agreed implementation objectives, unclear political or economic framework conditions, and changing stakeholder commitments, we find only loosely organized groups of stakeholders.

All cases were confronted with setbacks that often caused the innovation management to become active and responsive. The Italian IR team continuously adapted processes to setbacks; it provided alternative options to the stakeholders and decided during workshops on future pathways and strategies. Similar, in the Austrian case setbacks, such as key stakeholders departing to realize specific innovation ideas on their own or the perception of some stakeholders not being represented sufficiently in the innovation-related decision-making processes triggered activities on part of the IR team. The setbacks in the development of thematic innovation ideas even led to the development of a stakeholder platform as the central innovation idea. In the Finnish case, the major setback was caused by the reluctance of private actors to participate in piloting activities. The IR team pragmatically adapted the innovation content and stakeholder configuration when they searched for a regional public actor who was willing to participate in a pilot. All cases highlight the need for continuous adaptation of the innovation development by the innovation management as a reaction to unforeseen external events.

4.2. Key actors and their interests

In each of the four cases individual actors or stakeholder groups became mainstays of the innovation developments. They carried and led the process and triggered or influenced key turning points significantly. In the Italian case, members of the state administration, most prominently the director of the forest district of Primiero, carried the innovation as persons of authority. The administration organized meetings and engaged stakeholders, with their offices as supporting and legitimizing entities in the background. In Eisenwurzen, the Federal Environment Agency and the National Park Gesäuse had been involved in the project planning activities. Yet, their involvement in strategic and operational planning decreased over time. Instead, a small group of committed entrepreneurs drove innovation development. In Finland, SYKE played an important role in the development of environmental policy instruments, and in the innovation development process it aspired to play a key role as an offsetting mediator. In the case of the Forest Share, ANE's management sought a key position in the further development and marketing of the Forest Share. In summary, we find that state organizations play an important role in developing governance innovations, in particular as managing actors. Yet, they are seldom the main change agents or the key driving force in innovation efforts.

4.3. Institutional and governance arrangements

In all cases, regulatory context conditions and existing funding schemes were influential elements of the institutional and governance arrangements. In the Austrian case, the production of tiny-houses and their placement for tourist use in national parks was an early scenario for innovation development. However, at the time the innovation was developed, no legal building regulations existed for tiny-houses. Furthermore, national park regulations prohibited visitors to stay in the park overnight. Given the uncertainty about legal hindering factors, the IR team decided to refrain from further developing this scenario. In the Italian case, Trentino province's Forest and Mountain Plan included more participatory elements to achieve the reconciliation of forest and pasture management. The regional innovation development process launched in 2017 can almost be considered a pilot for such an integrative approach. The importance of clear legal framework conditions became particularly apparent in the Finnish case. The concept of a Habitat Bank can, in theory, be realized as a governmental mechanism foreseeing the compensation of biodiversity-reducing development projects by law. In the absence of a legal obligation, it can also be implemented as a voluntary market instrument in which stakeholders,

such as large companies voluntarily compensate for the biodiversity impact of their business operations, for example, as part of a Corporate Social Responsibility strategy. However, the lack of legal requirements for compensation required a shift in the focus of the innovation development from private to public actors. While our innovation cases show that a reliable legal environment was a fostering institutional context condition, the specific impacts of regulations differed. Innovations cast in law were unable to develop with the changing situation and regulation was falling behind innovation developments in some regions.

In two of our cases, regional development funding supported innovation development. In the Austrian case, the IR Eisenwurzen had participated successfully as a part of LEADER from 2014 to 2020, financed by the European Agricultural Fund for Rural Development (EAFRD). The LEADER activities carried out in Eisenwurzen were the source of the initial innovation idea – modular furniture - and created the basis for its further development. Similarly, in the Italian case, the EAFRD had supported the innovation with funds (2014–2017), i.e., before the innovation development process started. Again, this set the foundation for future innovative developments in the region. Therefore, the EAFRD as seed funding was a successful tool not only in developing rural areas in Europe, but also supported the creation of innovative approaches.

4.4. Biophysical and technical conditions

Various natural disturbances occurred that impacted upon innovation development in each of the four cases. The Italian IR was heavily hit by the Vaia storm resulting in a major change of biophysical conditions. The high loss of forest cover impacted economic conditions, as the resulting oversupply of timber led to a drop of the timber price, and, in turn, affected the constellation of stakeholders. In Eisenwurzen, the low timber price threatened the existence of small businesses; forest owners often even left the timber in the forests instead of selling it. In the case of the Forest Share, climate change related forest fires and droughts as well as a desired educational impact on the society had led to the development of the initial innovation idea of a compensation scheme in 2007. Similarly, the Habitat Bank of Finland idea, was initially driven by discourses on climate change. All cases were confronted with the Covid-19 pandemic outbreak and its direct and indirect impacts on the innovation development process. Covid-19 interrupted stakeholder processes and innovation management as well as policy-making processes. Overall, we observe that most of the crisis-related interruptions of innovation development were also an opportunity in radically changing pathways.

4.5. Innovation pre-history

In addition to our analytical dimensions in the project progression phase, we observed that different starting conditions, i.e. the pre-history of the innovation journey and the initiation phase played an important role for the development of each of the innovations analysed. In the Italian and Austrian cases, pre-existing innovation ideas were revealed at an early stage of the project. In both cases, pre-existing knowledge of actors and main features of those innovation ideas were evaluated and updated. The Forest Share in Germany even built on a running business model. The Finnish case picked-up on an existing network with a built trust relationship among involved stakeholders and on an innovation idea that had partially been developed in a previous project. In both cases, the aim of the innovation management was to further develop and adapt the stakeholders' established innovation ideas and to reinvigorate stakeholder interest. Overall, we find that investigating the history of the ideas and stakeholder networks that precede the actual innovation can provide valuable inputs for the innovation development process.

5. Discussion and conclusion

In this paper, we aimed at better understanding the development processes of governance innovations for the sustainable provision of FES. By reconstructing their development history over time, from first ideas up to running configurations for FES provisioning today, the innovation journey approach revealed empirical evidence of crucial influencing factors. Their separation into four main analytical categories: innovation management, actors, institutions and governance arrangements, and biophysical and technical conditions, allowed us to structure and focus our analysis to better understand the range of fostering and hindering factors that have influenced innovation developments, and how these played out in distinct contexts. Identifying key turning points in each innovation journey improved our analytical precision by isolating those combinations of key factors that are decisive for a specific key turning point. While usually (a combination of) factors covering more than one analytical dimension were explanatory for a certain key turning point, in most cases, only one of those analytical categories was found to be crucial. The cross-case comparison then revealed context-specific and common development patterns for these governance innovations. Comparable studies have been carried out recently to identify drivers and barriers to collective action for the achievement of EU water policy objectives in France (Amblard and Mann, 2021). Guided by a conceptual framework that combines institutional design principles and integrated landscape management approaches, the authors identified common influences as well as local factors on the implementation of EU water policy across agricultural landscapes.

As in other qualitative research, it was not always clear-cut as to how we would categorize and interpret the material in our analysis. For example, long discussions took place about how to classify certain events in the reconstruction of the innovation journeys, or the occurrence of influencing factors and dimensions, and about which events belonged to a key turning point. To ensure validity of the identified key turning points, five authors independently conducted the categorization, interpretation, and analysis steps, to then check intersubjective comprehensibility by discussions among interpreters until consensus was reached (Richards, 2015).

On a conceptual level, the combination of natural resource governance approaches with those from innovation studies proved helpful to identify the close interrelations between designing governance approaches on the one hand (e.g. Lemos and Agrawal, 2006), and the inherent innovation dynamics in their development (Geels and Schot, 2007; Van de Ven et al., 1999), that change designs along the way and with this may lead to different outcomes than expected. The innovation management in our cases, for example, adapting to changing circumstances proved to be particularly challenging. It included dealing with 'surprises' like sudden changes in the biophysical world but also changes in institutional arrangements like legislative frameworks or government-induced management plans. Further, substantial changes in the stakeholder composition or interests, including the 'loss' or sudden appearance of key actors, had to be accounted for, potentially slowing down innovation development or giving it 'a push' in a different direction. These insights make innovators, both from science and practice aware of the non-linear characteristics of such endeavours as well as the various intended and unintended side effects innovation activities might have. We provided evidence that adopting such an understanding, i.e., the limited controllability of processes is highly needed when designing and implementing governance approaches for FES provisioning. It emphasizes findings by Klerkx et al. (2010) that highlight the need for strengthening adaptive management capacities, for example through flexible support instruments, rather than relying on top down regulations. As an implication to deal with these rather uncertain development dynamics, conditions for innovation development can be created that allow for intentional governance design and, moreover, the need for continuous monitoring and adaptation of innovation processes along

their development.

For future governance innovation development processes, this implies the setup of protected spaces for innovation development, such as innovation platforms, as a first step. It subsequently allows for an open deliberation of stakeholder interests and expectations regarding FES provisioning. Stakeholder participation and exchange of experiences are preconditions for governance co-design work that is based on mutual learning and reflection. This may lead to more sustainable, i.e., societally embedded innovation endeavours that are adjusted to contexts and changing socio-political as well as biophysical conditions. In this vein, monitoring systems should be established as feedback and early warning instruments to detect when a governance innovation does not match the context of application or fails to reach intended objectives, and therefore requires adaptation.

Recognizing that there are multiple examples of governance innovations in Europe that successfully provide the full FES spectrum with functioning compensation mechanisms and collaborative efforts, the case studies discussed illustrate important pathways for mutual scientific-practice knowledge exchange and learning processes, and how to showcase functioning innovation development across sectors and scales.

Declaration of Competing Interest

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

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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