

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

# Forest Policy and Economics

journal homepage: [www.elsevier.com/locate/forpol](http://www.elsevier.com/locate/forpol)

## Addressing the challenge of wood mobilisation through a systemic innovation lens: The Irish forest sector innovation system

Kevin Kilcline<sup>a,\*</sup>, Áine Ní Dhubháin<sup>b</sup>, Kevin Heanue<sup>c</sup>, Cathal O'Donoghue<sup>d</sup>, Mary Ryan<sup>a</sup>

<sup>a</sup> Teagasc Rural Economy and Development Programme, Mellows Campus, Athenry, Galway, Ireland

<sup>b</sup> School of Agriculture and Food Science, University College Dublin, Ireland

<sup>c</sup> Evaluation Unit, Teagasc, Mellows Campus, Athenry, Galway, Ireland

<sup>d</sup> School of Arts, Social Sciences and Celtic Studies, National University of Ireland Galway, Ireland

### ARTICLE INFO

#### Keywords:

Forest policy  
New non-industrial private forest owners  
Sectoral innovation system  
Wood mobilisation  
Systemic problem  
Blocking mechanism  
functional-Structural analysis

### ABSTRACT

In the face of growing demand for sustainable sources of biomass, the challenge of mobilising non-industrial private forest landowners (NIPF) with varying management objectives, to actively manage their forests and increase the supply of wood biomass, is an area of growing research and policy focus. While innovation and knowledge exchange is increasingly viewed as a means of promoting sustainable wood mobilisation, structural weaknesses in the sector such as deficiencies in the institutional and infrastructural setting or capacity of stakeholders, can negatively influence innovation processes. Addressing these overarching challenges requires a systemic analysis of the barriers to innovation across the forest sector as a whole. This case study of the Irish forest sector develops a comprehensive innovation systems framework, integrating structural and functional streams of innovation systems research. This 'coupled structural-functional' framework is applied to identify a number of interconnected systemic problems that hinder the functioning of the forest sector innovation system and negatively influence the potential for co-innovation and wood mobilisation in the sector. Three sets of key systemic wood mobilisation problems are identified, among which there is negative feedback. These so called 'blocking mechanisms' have developed over time as a result of historical patterns of practice, prevailing culture, attitude and regulation and are defined here as (i) weak networks blocking capacity development of new forest owners, (ii) infrastructural problems blocking the reach and effectiveness of knowledge networks, (iii) rigid institutional structures and policy blocking co-innovation. To address these deficiencies in the current forest policy and institutional environment, this study makes a number of policy recommendations to promote co-innovation and tackle the multi-dimensional challenge of wood mobilisation.

### 1. Introduction

Growing societal and consumer preferences for renewable, sustainable products including sawn timber, wood energy and novel forest products underpin forecasts for increasing roundwood demand from EU forests and internationally (Hetemäki, 2014; Hurmekoski et al., 2018). This highlights the need for the EU forest-based sector to develop coherent long-term strategies for domestic resource mobilisation and to reduce the reliance on imported wood products (Orazio et al., 2017). Many EU member states (MS) have responded by developing national forest policies that recognise the need to sustainably harvest more wood from their forests while protecting the environment (Lawrence, 2018).

The literature on wood mobilisation points to a multitude of interconnected and often conflicting factors constraining the potential harvest of EU forests, including emerging and fragmented ownership structure (Ficko et al., 2019; Lawrence, 2018; Stern et al., 2013), social constraints and diverging management preferences of stakeholders (Kuuluvainen et al., 2014; Moffat et al., 2016; Toppinen et al., 2016), environmental and technical constraints (Mantau et al., 2010) and a range of other institutional and economic factors (Orazio et al., 2017). This paper employs a comprehensive systemic innovation approach to study the forest sector and examine these complex, interacting wood mobilisation challenges.

Wood mobilisation strategies aim to increase the sustainable harvest

\* Corresponding author.

E-mail addresses: [kevin.kilcline@teagasc.ie](mailto:kevin.kilcline@teagasc.ie) (K. Kilcline), [aine.nidhubhain@ucd.ie](mailto:aine.nidhubhain@ucd.ie) (Á.N. Dhubháin), [kevin.heanue@teagasc.ie](mailto:kevin.heanue@teagasc.ie) (K. Heanue), [cathal.odonoghue@nuigalway.ie](mailto:cathal.odonoghue@nuigalway.ie) (C. O'Donoghue), [mary.ryan@teagasc.ie](mailto:mary.ryan@teagasc.ie) (M. Ryan).

<https://doi.org/10.1016/j.forpol.2021.102461>

Received 19 July 2019; Received in revised form 5 March 2021; Accepted 17 March 2021

Available online 19 April 2021

1389-9341/© 2021 Elsevier B.V. All rights reserved.

of biomass from forests by addressing these barriers to active management (Ní Dhubháin, 2015) and are a growing area of policy and research focus. Much of the international literature to date has focused on identifying and addressing those supply side challenges associated with forest ownership change (UNECE/FAO, 2020; Ficko et al., 2019; Živojinović et al., 2015) in particular the emergence of new non-industrial forest owner (NIPF) types either through inheritance, restitution processes or afforestation (Weiss et al., 2019; Lawrence, 2018; Ní Dhubháin, 2015). Studies of these 'new' forest owner types (Weiss et al., 2019; Lawrence, 2018; Ní Dhubháin et al., 2015) address topics such as the impact of changing motives, goals, and management objectives (Ficko et al., 2019); Pöllumäe et al., 2014), how management practices are informed by either traditional forms of knowledge transfer (Upton et al., 2017) or inclusive, formal (Ma et al., 2012) and informal (Lind-Riehl et al., 2015) peer-to-peer knowledge networks.

In countries where private ownership accounts for a significant portion of the forest estate, wood mobilisation is dependent on the interest and commitment of private owners and their links with forest management services, harvesting contractors and markets (Lawrence, 2018). With a young, expanding, highly productive private forest estate (Farrelly et al., 2009), the Irish forest sector makes a particularly interesting case to investigate the challenge of wood mobilisation. Recent roundwood supply forecasts (Phillips et al., 2016) project national output to double over the next two decades, driven almost exclusively by a fivefold increase in private roundwood harvest. These forecasts assume that private forests, planted since the mid-eighties with the support of afforestation capital grants and afforestation subsidies (DAFM, 2020), will be managed commercially to maximise net present value by employing the same intensive thinning/clearfell silvicultural system as state managed (Coillte) forests (Ní Dhubháin et al., 2015; Phillips et al., 2016). Unlike most other European States, private forest ownership in Ireland is dominated by new forest owners, the majority of who are farmers (81%) engaging in forestry for the first time (Duesberg et al., 2014; Upton et al., 2014; DAFM, 2020). These new owners have little knowledge or experience of farm forest management, in contrast to forest owners in countries with a longer tradition of farm forestry (Weiss et al., 2018) and considerable uncertainty surrounds both their intentions and capacity to actively manage their forests (Upton et al., 2017).

While Ireland has the second lowest forest cover in the EU at 11.2% of land area (EUROSTAT, 2018), a significant investment in afforestation has been made through EU and national funding instruments with the explicit goal of developing the capacity for wood production, initially through State afforestation and subsequently through private afforestation incentives targeted at farmers (Neeson, 1991; DAFM, 2014). While total forest cover is low, it has increased significantly from 1.2% in 1928 and continues to grow, demonstrating the second highest growth rate in private planting in Europe since 1990 (UNECE/FAO, 2020). Currently, 49.2% of the national forest estate is under private ownership, with over 74% of private forests established since 1980 with the support of state afforestation programmes (DAFM, 2020). However, despite financial incentives, recent years have seen afforestation rates plummet to the extent that only 2300 ha were planted in 2020 compared to an average of 11,000 ha in the previous 30 years. This is driven by a tenfold decrease in farmer planting since 2015 when it accounted for 6400 ha or 95% of private planting (2009 to 2014 6 year average) compared to only 580 ha or 36% of private planting in 2019 (DAFM, 2020). While trends in afforestation are multifactorial, the changing policy environment and equalisation of afforestation grants and subsidies for farmers and non-farmers since 2014 has had a considerable impact.

To avoid the forecast shortfall in domestic timber supply requires renewed afforestation levels in addition to active management of the plantation forests in the private estate (Duesberg and Ní Dhubháin, 2019)). Given the profile of private planting in Ireland and the spike in afforestation in the mid-1990s (Fig. 1), the mobilisation of the private

forest resource at or approaching first thinning stage is imperative. While private harvesting operations are increasing, the vast majority of roundwood supply for the processing sector currently derives from Coillte (the state forest company that manages the public forest estate). Furthermore, there is evidence that the required level of innovation in private management is not keeping pace with roundwood demand and a significant portion of thinning-ready private forests remain unthinned. The most recent National Forest Inventory (DAFM, 2017) highlights the lack of active management, categorising a quarter of Irish privately owned forests as un-thinned. While thinning may be imminent for some forests, and other forests may not have been thinned to date for a variety of reasons such as high windthrow risk, economic factors or alternative management objectives, there remains significant potential for more active management and increased thinning intensity. Private forests in Ireland are also highly productive and with a growing demand for roundwood (COFORD, 2015), the Irish forest sector has strong potential to increase roundwood supply (Phillips et al., 2016) should barriers to private forest harvesting be overcome (Ní Dhubháin et al., 2015). However, this not only challenges the management capacity of inexperienced forest owners but the collective capacity of the wider sector to innovate and address a range of overarching and interconnected environmental, infrastructural and institutional constraints.

Most Irish studies have focused on investigating individual factors constraining forest management and mobilisation, particularly the effectiveness of extension interventions in addressing deficiencies in forest owner knowledge and assessing their contribution to management capacity-building with a view to satisfying timber production goals (e.g. Maguire et al., 2010; Ní Dhubháin et al., 2010; Upton et al., 2017). The role of recently established forest owner groups in network-building and knowledge diffusion has also been investigated (Stoettner and Ní Dhubháin, 2017). Few sectoral studies or reports have sought to diagnose the overall performance of the sector and identify the range of constraints to mobilisation. Notable exceptions include a series of reports from the COFORD<sup>1</sup> Wood Mobilisation Group (COFORD, 2015; COFORD, 2018b) which purported to identify "most if not all of the issues affecting wood supply and demand on the island of Ireland". While these reports provided the first in-depth study of mobilisation challenges in Ireland and proposed how they might be addressed by industry and state agencies alike, they did not investigate the underlying insitutional conditions and stakeholder relationships developed over time.

Scientific papers and national reports on best practice in silvicultural management, and harvesting innovations are relatively abundant (Lawrence, 2018). Numerous papers develop technical solutions to increase harvest recovery and improve harvest efficiencies (Eisenbies et al., 2009; Helmisaari et al., 2014). Studies of technical and infrastructural solutions to wood mobilisation in the Irish forest sector have also been conducted (e.g. Devlin and McDonnell, 2008; Devlin and Klvač, 2014; Sosa et al., 2015; Rivera and Nieuwenhuis, 2018). While technical solutions are important, research must not only develop silvicultural technologies but must also reflect on how readily adoptable these technologies are on the ground and evaluate the actual contribution of adoption (Lawrence, 2018). Innovation in wood mobilisation thus needs the buy-in and interaction of a multitude of stakeholders across the public and private sectors including forest owners, managers, contractors, and roundwood buyers.

Research on the social acceptability of established forest management practices among wider forest sector stakeholders (Marsden et al.,

<sup>1</sup> The COFORD forest council is a body appointed by the Minister for Agriculture, Food and the Marine to advise the Minister and his Department on issues related to the development of the forest sector in Ireland and includes a number of expert working groups set to tackle specific issues of strategic importance to the Irish forest sector. Its membership is appointed by the Minister and comprises stakeholders from across the forestry sector

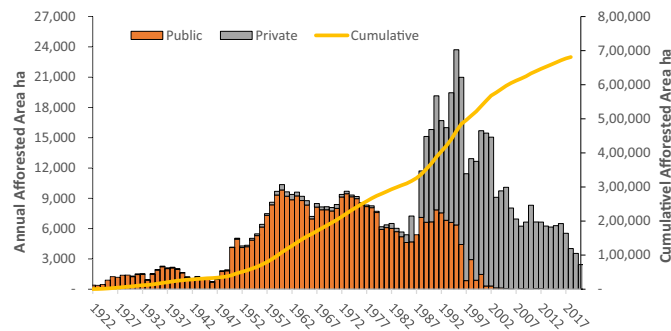


Fig. 1. Private and public planting in Ireland (1922–2019) (source: Forest Service statistics).

2003; Ribe, 2006; Edwards et al., 2012) is increasingly relevant to understand the potential for forest resource mobilisation. The growing demand for multifunctional forestry is associated with institutional innovation and new incentives for the delivery of public goods. This reflects a re-orientation away from traditional technical innovation in the sector, focused on wood production and wood supply chains (Buttoud et al., 2011).

The literature on wood mobilisation in Ireland indicates that this is an unprecedented sectoral challenge not only for an emerging group of inexperienced private forest owners but for sectoral value chains in general and the wider sectoral institutions (COFORD, 2015; Ní Dhubháin et al., 2015) and is the subject of growing policy, industry and research focus (COFORD, 2015; IFFPA, 2018; Ní Dhubháin, 2015). Reflecting the multi-dimensional nature of the wood mobilisation challenge, the EU-funded pan European SIMWOOD project identified the most effective wood mobilisation solutions as those which take account of such inherent complexity through multifaceted approaches “developed and tailored to local social and political conditions as well as environmental and economic conditions” (Orazio et al., 2017, p.414). In line with this perspective and in comparison to previous studies, this paper takes a broader, systemic and holistic approach to studying wood mobilisation in Ireland. Thus rather than focusing on investigating individual technical or institutional solutions to forest management and mobilisation, this study conceptualises innovation in the Irish forest sector as a complex process taking place in a wider environment of multiple interacting actors and institutions (Rametsteiner et al., 2010). The goal of this study is thus to (a) determine whether the current Irish forest sector structures and institutions are appropriate to support the innovation necessary to respond to the wood mobilisation challenge and increase timber output sustainably, and (b) where deficiencies are detected, suggest how they can be improved. To address this goal, this study employs an innovation systems framework to diagnose the performance of the forest sector through the structured analysis of interviews with key sectoral stakeholders, from research and extension, through to commercial actors across the value chain, to government actors.

The next section describes how innovation in the forest sector has previously been conceptualised. Building upon these foundations and drawing from the innovation studies literature, a broader systemic representation of innovation and a complementary analytic framework is proposed to study wood mobilisation in Ireland. The results section presents the interacting systemic innovation challenges (blocking mechanisms) identified through a structured ‘coupled structural-functional’ analysis (Wieczorek and Hekkert, 2012) of stakeholder interviews, along with supporting information from an analysis of academic and grey literature. The discussion and conclusion sections reflect on the performance of the innovation system, identifying knowledge gaps that require further attention and suggesting coherent recommendations for strengthening innovation capacity across the sector.

## 2. Conceptualising the forest sector innovation system

The systemic perspective on innovation has emerged over the last half century in the science and policy arena in response to the limitations of the simplistic ‘transfer of knowledge’ or ‘science push’ model. The science push model views innovation as the product of a linear process of technological knowledge, i.e., an invention, transferring from research through extension services to end users (Edquist, 2013). The broader systemic perspective on the other hand views innovation as a social process resulting from multiple interactions between components of the system, supply chains and economic systems, policy environments and societal systems (Klerkx et al., 2012).

The recent COST Action project, FACESMAP (Forest Land Ownership Changes in Europe: Significance for Management and Policy) assessed the policy implications of changing forest ownership structures across Europe. FACESMAP identified the need for broader, more holistic and systemic approaches to guide the development of forest policy instruments and forest management approaches, in order to account for the growing diversity of perspectives on forest management across stakeholders and among new forest owner types. In particular, Weiss et al. (2016, p.16) propose the need for a systemic conceptual framework to study the range of different sectoral knowledge services and how they interact together “in the way that AKIS looks at Agricultural Knowledge and Information (or Innovation) Systems in a holistic way”. Lawrence et al. (2020) develop this parallel conceptualisation by adopting the (AKIS) concept from the agriculture domain and proposing the term Forestry Knowledge and Information Systems (FOKIS) to understand innovation processes in the forest sector. This conceptualisation encapsulates both the knowledge system (a purposeful and interdependent group of sectoral actors) and a method for understanding innovation processes through analysis and assessment of the various actors within the advisory system as well as their communication and interaction. Thus the (FOKIS) provides a framework for better understanding the role and performance of the forestry advisory system.

The innovation systems (IS) literature goes further, recognising that innovation is the outcome of an interactive and co-evolutionary process (Smits and Kuhlmann, 2004) and emphasising that innovation is not just about new technologies but also about institutional change. Accordingly, we propose an innovation system approach to study innovation processes and their role in supporting wood mobilisation, taking a broad frame of reference by analysing the roles of an extensive group of actors within the innovation system, not confined to formal and informal knowledge networks. This approach is particularly relevant to study the forest sector, which is commonly referred to as a ‘low-tech’ or ‘traditional’ sector, where formal R&D pathways are often not the key driver of innovation processes (Weiss et al., 2011). Instead, innovation in the forest sector may come through alternative pathways such as new markets and marketing approaches, new value chain structures, new combinations of production, etc. (Kubeczko et al., 2006; Nybakk et al., 2015).

While the definitions of innovation system (IS) and knowledge and

information system (KIS) presented here are similar and overlapping, they have been viewed in the agriculture domain as distinct, parallel literatures. In line with Klerkx et al.'s (2012, p. 463) observations on the evolution of systems approaches to agriculture innovation, the main difference between the innovation system (IS) conceptualisation of innovation proposed in this study and the (FOKIS) concept proposed in Lawrence et al. (2020), lies in the IS's "greater and more explicit focus on the influence of institutions (seen as organisations like companies, public research institutes and governmental entities) and infrastructures". The broader definition of the IS concept is more useful in the context of the wood mobilisation challenge where the role of markets, the private sector, and the wider enabling environment is crucial.

In line with the literature on sectoral innovation systems (Lampirinopoulou et al., 2014; Spielman and Birner, 2008), key actors in the sectoral innovation system are classified in this study according to the four broad categories of Arnold and Bell's (2001) typology, namely: research, enterprise (value chain actors), influencing (influencing actors and institutions), and intermediary (bridging institutions) domains. Fig. 2 presents a simplified representation of a forest sector innovation system. While the categories are not mutually exclusive, the conceptualisation provides guidance on the type of actors that are likely to be important to the functioning of the sector and act as a starting point to identify the organisations to interview within a defined system boundary. The IS conceptualisation in Fig. 2 can be seen to draw a wider system boundary, including the contribution of wider sectoral institutions and value chain actors, beyond the scope of the FOKIS concept and its focus on knowledge networks (Lawrence et al., 2020; Klerkx

et al., 2012).

The research domain encompasses state-funded universities and research institutions, as well as private companies (with their own formal research and development functions). The enterprise or value chain domain on the other hand, includes all those value chain actors (e.g. input suppliers, forest owners, forest companies, wood processors, wholesalers and retailers) who typically use and produce tacit knowledge as opposed to formal scientific (codified) knowledge. The intermediary domain includes those bridging organisations that may not necessarily be involved in knowledge creation, but act as intermediaries connecting disparate actors to facilitate knowledge exchange and innovation flows. Bridging organisations include public extension services, private forest consultancies, forest owners, representative bodies and industry working groups. The influencing domain refers to the group of socioeconomic institutions and infrastructural conditions that directly shape the innovation environment in the sector, including: public policies on innovation and forestry, informal institutions that establish the rules, norms, and cultural attributes of a society, and the behaviours, practices, and attitudes that condition the ways in which individuals and organisations within each domain act and interact. Beyond the borders of the system lie the external factors that indirectly influence forest innovation including: general policies on science and technology, the wider political system, other sectors of the economy, international actors, knowledge and best practice.

Different approaches exist for analysing an innovation system according to the focus of a particular study, whether spatial (national or regional) (Lundvall et al., 2002; Nelson, 1993), sectoral (Breschi and

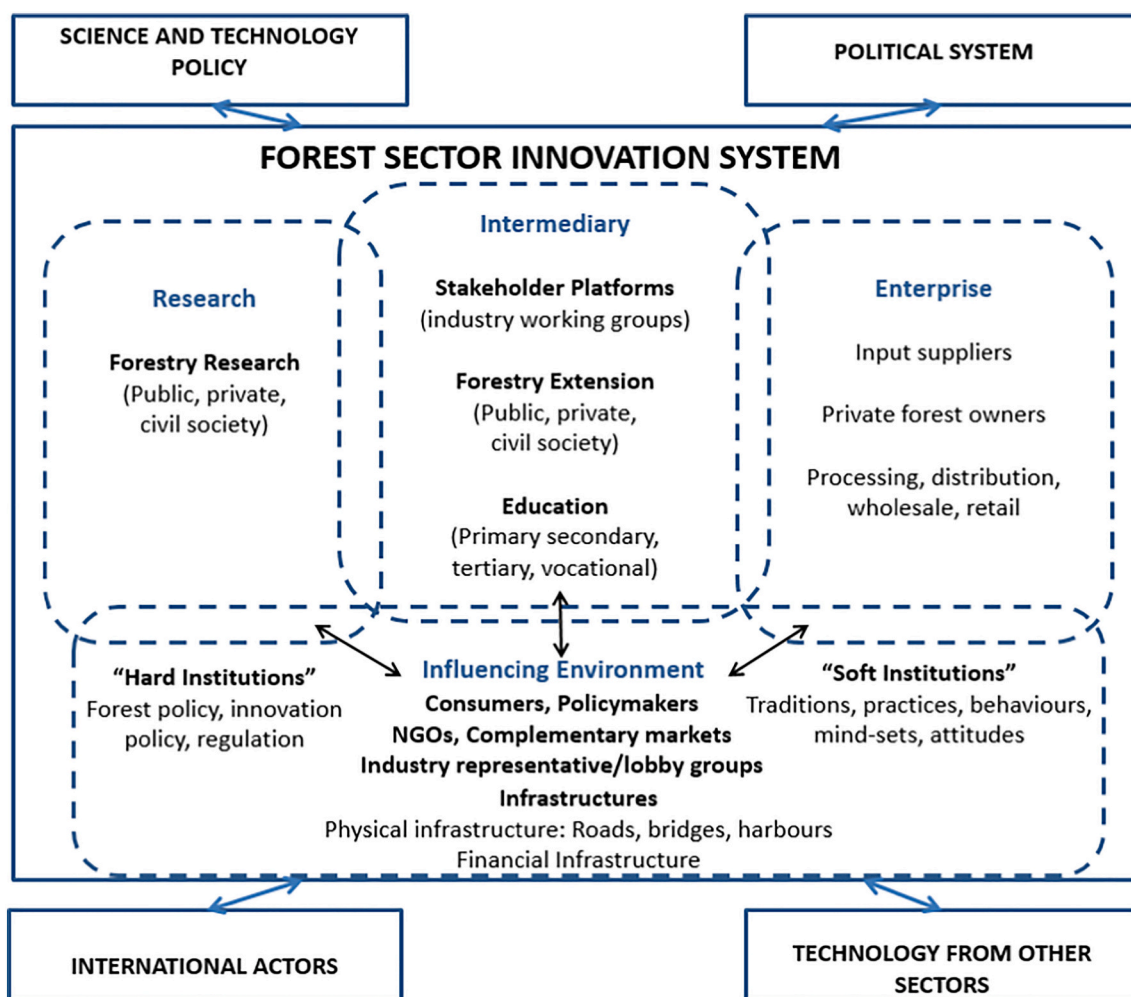


Fig. 2. Conceptual diagram of a forest sector innovation system (adapted from Arnold and Bell. (2001) "Components of a National Innovation System").



Malerba, 1997; Malerba, 2004) or technological (Bergek et al., 2008; Hekkert et al., 2007). Sectoral innovation systems (Malerba, 2002, 2004) have been commonly used as an analytical framework in which to view innovation within a specific sector of the economy (Edquist, 2013) and there have been previous applications to the study of timber-related innovations in the forest sector in Europe (Jarský, 2015; Kubeczko et al., 2006; Rametsteiner and Weiss, 2006). The technological innovation system (TIS) perspective has also been applied to analyse the emergence and evolution of the Finnish wood-frame multi-storey construction sector (Lazarevic et al., 2019).

In this study, we adopt the World Bank definition of a sectoral innovation system to study the forest sector in line with the conceptualisation presented by (Hall et al. (2006, p. 14), i.e. the “network of organisations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organisation into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge”. From this perspective, co-innovation in a sector results from the interaction of the diverse set of actors who come together to co-develop knowledge, new business models and value chain structures, and drive technological developments and institutional reforms (Turner et al., 2016). The structural composition and performance of an innovation system determines how well it supports the set of innovation system functions necessary to support collaboration and co-innovation (Bergek et al., 2008; Hekkert et al., 2007; Johnson, 2001).

### 2.1. Analytical framework: A structural-functional analysis of the forest sector innovation system

The structural performance of an innovation system is diagnosed by assessing the presence and quality of its structural elements, namely the **presence and competency of its actors**, the **nature (presence and quality) of their interactions**, the **presence and quality of physical, financial and knowledge infrastructures**, and the role (**presence and quality) of institutions** in influencing actors' decisions and providing a supporting environment for collaboration (Klein Woolthuis et al., 2005). From this perspective the presence and quality of the structural aspects can be seen as determinants and drivers of system functioning (functions) and performance. Despite the clear link between the structural and functional aspects of innovation systems, studies of sectoral innovation performance tend to focus on one or the other. Most commonly, the focus is on the analysis of the structural problems in a sector (Klerkx et al., 2012), often using Klein Woolthuis et al.'s (2005) systemic problems or framework. This systemic framework has not been used to date to study the forest sector. Notwithstanding the focus of the systemic failures framework on diagnosing structural problems it can also be used to identify the relative structural merits or strengths of the system.

In contrast, functional analysis approaches focus on identifying the functions of innovation systems as key motors of innovation performance and resulting technical change. This functional approach has previously been applied in a number of studies of technological innovation in the forest sector (Jarský, 2015; Kubeczko et al., 2006; Rametsteiner and Weiss, 2006; Lazarevic et al., 2019). There are numerous classifications of innovation system functions with Jarský (2015); Kubeczko et al. (2006); Rametsteiner and Weiss (2006) all adopting the typology proposed by Edquist and Johnson (1997). On the other hand, Lazarevic et al. (2019) adopt the more recent typology of Hekkert et al. (2007) to assess innovation in wood-frame multi-storey construction in Finland. This study similarly adopts the Hekkert et al. (2007) typology of seven functions (F1 – F7). (F1) **Entrepreneurial activities**, (F2) **Knowledge development**, (F3) **Knowledge diffusion**, (F4) **Guidance of the search**, (F5) **Market formation**, (F6) **Resource mobilisation**, (F7) **Creation of legitimacy/counteract resistance to change**. The numbering of functions is used solely for clarity in the presentation and discussion of results, in order to identify the linking of system functions affected by various structural components in the

integrated analysis. Most of the functions are self-explanatory except for (F4) Guidance of the search which refers to creating a vision for the innovation system that orientates other functions towards meeting agreed priorities for the sector. This is influenced by strong societal preferences or long term policy goals, which influence the acceptance of specific technologies or trajectories for achieving those goals. For a detailed discussion of the various functions see Hekkert et al. (2007).

In order to diagnose the performance of the forest sector innovation system this study integrates both structural and functional streams of analysis by taking account of both the presence and quality of the structural elements and their impact on functions of innovation in line with the comprehensive ‘coupled structural-functional’ framework proposed by Wiecek and Hekkert (2012). There have been a number of applications of this framework to other land use sectors, in particular agriculture (Kebebe et al., 2015; Lamprinopoulou et al., 2014; Turner et al., 2016) but also energy efficient construction (Kieft et al., 2017). To date, it has not been applied to a systemic analysis of the forest sector. As outlined in Kebebe et al. (2015), the Wiecek and Hekkert (2012) structural-functional analysis framework brings together the alternative pre-existing frameworks, previously outlined, which emphasise different aspects of innovation systems (structure/systemic failures, functions) into a comprehensive analytical and diagnostic framework. This enables analysis of the effectiveness of the key functions that support co-innovation, according to Hekkert et al.'s (2007) typology, along with analysis of the presence and quality of the structural components, according to Klein Woolthuis et al.'s (2005) systemic problems framework, required to make those functions effective.

This coupled structural-functional analysis thus aims to go further than previous forest sector innovation system studies by linking systemic problems to particular functions. It also focuses on identifying the shared underlying issues that influence the performance of several interacting functions, and provides suggestions for systemic instruments that enhance the coordinated performance among these functions. This is achieved by identifying where certain combinations of systemic problems are linked to each other as a result of historical patterns of practice, prevailing culture, attitudes and rules which have developed over time (Turner et al., 2016). These so-called ‘blocking mechanisms’ are identifiable persistent mechanisms which are evident where several interacting systemic problems work together to negatively impact on system functions and co-innovation. This is in line with the conceptualisation of blocking mechanisms proposed by Kieft et al. (2017) who argue that such an approach adds value especially for innovation systems that are mature and in transition. The Irish forest sector can be regarded as mature and faces the challenge of achieving sustainable forest management (SFM) (Upton et al., 2012) while increasing wood mobilisation, thus making an explicit analysis of problem interactions highly relevant.

Mature systems are characterised as locked into certain technological combinations and sector structures (Kieft et al., 2017). The Irish forest sector innovation system is considered a mature sectoral innovation system locked into a developed management and supply system which has evolved over time in the historical context of a state owned monopoly roundwood supplier (Coillte) (Clinch, 2000). Technological and institutional lock-in is not necessarily problematic in itself and the incumbent system can be seen to have developed effective and efficient routines to deal with supply challenges from public forests. However, when a transition is desired as in the case of emerging private roundwood supply from new non-industrial private forest owners (NIPF), the locked-in nature of the system can potentially inhibit change and become the source of problems itself if not remedied. In the Irish forest sector the emergence of private supply from over 23,000 new private forest owners brings a range of interconnected systemic challenges. Addressing these interacting ‘blocking mechanisms’ requires innovation across supply chains, institutional reform and new and enhanced forms of cooperation and collaboration.

### 3. Methodology

In line with many diagnostic sectoral innovation studies (Jarský, 2015; Kubezko et al., 2006; Turner et al., 2016) this study takes a qualitative research approach based on interviews with key sectoral stakeholders, supported by a literature review and document analysis (i. e. key forest sector reports, sectoral policy and policy review documents). Face to face semi-structured interviews were undertaken with individual stakeholders to allow a degree of flexibility for the interviewer to explore interesting insights in more detail and to allow the interviewee to talk about their personal experiences, topics of interest, etc. This corresponds with the aim of the interviews, which was to obtain an overview of the current status of the Irish forest sector as it is perceived by actors in the system and how it facilitates resource (wood) mobilisation (Turner et al., 2016). In line with the stepwise analysis approach proposed by Wieczorek and Hekkert (2012) and applied by Kieft et al. (2017) and Lamprinopoulou et al. (2014), interview structure and questions were designed to cover the various aspects of the ‘coupled structural-functional’ analytical framework previously outlined, namely: (i) identify the structure of the innovation system including important structural problems or merits in the sector (Annex A) and (ii) investigate how these structural aspects link to the functions/functional performance of the sector (Annex B).

To create a picture of the structural elements of the system social network analysis (SNA) techniques are used to describe the relationships between stakeholders in the sector (Rickenbach, 2009). Interviewees were asked to describe their (or their organisation’s) roles and experiences in the forest sector through an egocentric network mapping exercise. To facilitate the drawing of interviewees’ egocentric social networks, Net-Map, an interactive interview based social networking tool was used (Schiffer and Hauck, 2010). This tool has previously been applied to study the social networks (egocentric networks) of Irish private forest owners participating in forest owner groups (Stoettner and Ní Dhubbáin, 2017). Using Net-Map, interviewees were asked to draw a network of all the organisations in the forest sector with whom they were in contact or who influenced their interactions in the context of wood mobilisation. An interview guide was developed to direct discussion to identify interviewees’ perspectives and experience of wood mobilisation. In particular the network mapping was enriched by asking interviewees to identify the various institutional and infrastructural barriers negatively influencing the interactions and thus constraining wood mobilisation, as well as identifying promoters of active management, harvesting and windows of opportunity. Interviews were recorded and ranged in length from 50 min to 2 h and 20 min. Thematic analysis of the interviews was conducted (Merriam and Tisdell, 2015) to identify recurring themes and provide insights into the structure of the sector, the relative importance and impact (positive or negative) of structural factors on the seven innovation functions.

Purposive sampling was used to identify an initial group of key stakeholders from across the sector and interviews were conducted in spring 2018. This purposive approach to sampling was chosen as it is an effective and reliable way to secure a purposive representation of stakeholder types from across the forest sector (Scott, 2011). Interviewees, acting as respondents, described their own networks and experiences, and as informants, described the broader picture of the sector and observations on the institutional environment. An initial group of 12 interviewees was selected based on their expert knowledge of a particular aspect of the wood value chain, and also on their ability to comment on the forest system more generally. An additional 15 interviewees were selected through snowball sampling to capture a comprehensive representation of key stakeholders. In total, data were gathered from 27 forest stakeholders.

Interviewees are classified in Table 1 according to the four actor domains described in Arnold and Bell’s (2001) typology namely: research, enterprise, influencing, and intermediary. These domains and indeed the general description of the roles of the 27 interviewees are not

**Table 1**

Description of the stakeholders interviewed by actor domain.

Stakeholder group/Domain	Stakeholder organisation	Background of stakeholders and number interviewed
Research	Teagasc	The national agriculture and food development authority providing advice, training and research on farm forestry and related matters (1)  - Senior researcher in forest management University engineering department (1)
	University Research	- Academic researcher on sustainable bio-based construction products, including engineered wood products and wood chain optimisation Private research firm (2)
	Private Research Consultancy	- Directors of research company involved in research on forest management and timber harvesting. Farm forest owners (3)
Enterprise	Private landowners/farmers	- Farmer forest owners with experience of forest management from planting to harvest - Leading members of their local forest owner groups Forest Investment Fund (1)
	IForUT (Irish Forestry Unit Trust)	- Senior executive at forestry fund - Largest private forest owner and supplier of roundwood to the timber processing sector Private roundwood processor (3)
	Private roundwood Processor	- Manager of large roundwood processing plant - Director of smaller niche processor - Director of medium specialist processor Tree nursery (1)
	Nursery Company	- Manager of large nursery company supplying planting stock to the national afforestation programme Forest contracting company (1)
	Forest Contactor	- Director of private forestry contracting firm specialising in thinning and harvest operations The State forestry company (Coillte) (1)
Influencing	Coillte/State Forestry Company	- Commercial Director in sales and marketing with experience of management and harvest operations Local Authority in area with high level of forest cover (1)
	Local Government	- Senior Engineer with responsibility for road management Main organisation representing the interests of farmers/private forest owners at both National and European levels (1)
	Irish Farmers Association (IFA)	

(continued on next page)

Table 1 (continued)

Stakeholder group/Domain	Stakeholder organisation	Background of stakeholders and number interviewed
	Enterprise Ireland	- Senior executive for forestry committee Irish state economic development agency focused on helping Irish-owned business deliver new export sales (1)
	Media	- Senior executive global markets timber, print and packaging at Enterprise Ireland Journalist (1) Specialist Forestry Communications Consultant
	Forest Service	Authority responsible for regulating key forestry activities (e.g. afforestation, forest road construction, thinning and felling/replanting) under the 2014 Forestry Act (2) Forest service staff from the inspectorate and research functions
	Forest Industry Ireland (FII)	Representative group for companies from across the forestry and timber supply chain (1)
Intermediary	Private consultant and extension	- Senior executive Private consultancy involved in extension and coordinator of forest owner certification group (1)
	Private Forestry Companies	- Company director Companies specialising in farm forestry management, planting, management and harvest operations (2)
	Teagasc	- Regional manager/timber sales manager of large private forest company. - Director of cooperative providing professional services to farm forest owners The national agriculture and food development authority providing advice, training and research on farm forestry and related matters (2)
		- Extension agent - College forestry lecturer

mutually exclusive. Due to the multiple roles played by many actors and given that these roles evolve over time; actors can be classified as belonging to multiple domains (Lamprinou et al., 2014). A notable example is Teagasc, the Irish Agriculture and Food Development Authority, which is unique in Europe in that it constitutes a substantial component of the formal Knowledge System (KS) for both the agriculture and forest sectors in Ireland, providing publicly funded research, education and extension services within a single organisation (Prager and Thomson, 2014) This is reflected in the description of interviewees in Table 1 and their categorisation based on their main role and area/domain of contribution. The multiple roles that Teagasc covers is evident in Table 1, with three Teagasc interviewees contributing to the system across their distinct roles; education, extension and research.

Qualitative analysis of these in-depth interviews was complemented with an analysis of policy documents and industry reports, enabling triangulation of interview responses to ensure validity. Again the analytic 'coupled structural-functional' framework (Wieczorek and

Hekkert, 2012) was used to guide the document analysis to provide evidence on the structural and functional performance aspects of the sector. Relevant findings from this analysis which back up insights from the interviews are referenced throughout the results commentary and discussion.

#### 4. Results

The results of the structural systemic problems analysis are presented in tabular form in Appendix A. This is a failures matrix which cross-tabulates the various categories of systemic problem against actor groups (domains), thereby identifying both the nature of structural problems (whether infrastructural, institutional, interaction or capabilities), and the source of problems i.e. the relevant contributing actor group. This is in line with the presentation proposed by Klein Woolthuis et al. (2005) and applied in structural analyses of sectoral innovation systems such as Gildemacher et al. (2009). Structural observations represent either negative problems or positive merits which in themselves implicitly reflect interviewees' judgements on the nature (direction) of how the structural factors impact innovation functioning. This highlights that it is the functions of the innovation system that make structures meaningful (and vice versa) and reiterate the need for a coupled structural-functional approach for comprehensive systemic analysis (Wieczorek and Hekkert, 2012). Appendix A is to be most usefully viewed as a checklist for thinking about the structure and boundaries of the sector and as a step to understanding how structural factors impact on system functions.

The results of the integrated coupled structural-functional analysis are presented in Appendix B and make explicit the relationship between structural and functional observations. Structural problems impacting on the functioning of the Irish forest sector are identified and linked to the performance of innovation processes observed in the sector. Understanding the mechanisms by which the weaknesses in system functions affect innovation is necessary for designing interventions that deal with the complexity of constraints. This analysis identifies the functions that are perceived as weak, as well as the systemic problems that are contributing to this weakness. While Appendix B provides the basis for the preceding commentary of results, the aim is not to provide a description of each individual structural failure and merit in the table and how each relate to system functioning. In order to clearly and concisely capture key narratives on innovation performance expressed by interviewees, we focus our commentary on three systemic blocking mechanisms which emerge from a synthesis of key findings in Appendix B.

These blocking mechanisms relate to the underlying institutional setting which over time creates the conditions for groups of persistent, interacting structural problems which negatively impact on system functions and co-innovation. Blocking mechanisms identified in this study are characterised as arising from: (i) weak networks blocking capacity development of new forest owners (ii) infrastructural problems blocking the reach and effectiveness of 'knowledge networks' and (iii) rigid institutional structures and policy blocking co-innovation and sustainable transitions.

##### 4.1. Weak networks blocking capacity development of new forest owners

New private forest owners are characterised by their limited experience and knowledge of forest management and poor connection with the network of forest sector actors, including other forest owners (Weiss et al., 2018). The creation of a positive environment to encourage the active management and participation of private forest owners is thus a major component of the wood mobilisation challenge in Ireland where the majority of private planting has happened since the introduction of support schemes in the 1980s (DAFM, 2020) (Fig. 1). Interviews with sectoral stakeholders identified negative impacts on network development and management capacity development of forest owners caused by

weaknesses in the historic institutional settings and failure of established sectoral actors to actively encourage the involvement of new owners in the initial forest establishment and early management phase. In this context, three interlinked systemic interaction or network problems are identified which relate to institutional deficiencies which undermine the potential for capacity development among new forest owners.

Firstly, deficiencies in the formal institutional set-up were identified in interviews with both forest owners and advisors, particularly in the structure and operation of afforestation supports. While both acknowledged that supports are vital to encourage afforestation, the structure of the scheme and the growing complexity of administration (afforestation applications and other schemes, harvesting licences, etc.) deter owners from actively engaging in the initial planning, formative establishment and subsequent management of their forests. Instead these are seen as the responsibility of forest management companies and professional foresters. This removes agency from individuals, fostering disconnect between private owners, the management of their forests, and the market for their crops and thus hindering from the outset the functions of (F3) knowledge diffusion (F2) knowledge development and (F1) entrepreneurial activities.

Secondly, the operation of the afforestation grant scheme leads to a 'strong network' problem, whereby the reliance of forest owners on management companies as a source of information effectively locks owners into a dominant relationship with forest companies to the exclusion of other actors. The 'strong network' problem is seen to create an inward looking perspective, blocking innovative approaches and openness to new relationships and ideas (Klein Woolthuis et al., 2005). This in turn has reinforced the 'weak network' problem, defined by poor connectivity among forest owners and with downstream processors and knowledge providers. Indeed, this missing "linkage between the grower and the market, which is contrary to a strategy for any productive sector" was highlighted in a strategic review of the sector (Malone, 2008, p.14). This 'weak network' problem is defined as an interaction presence problem, whereby actors are not well-connected and the process of co-learning and innovation is prevented because there is no "creative recombination of knowledge, technologies and practices and resources" (Klerkx et al., 2012, p.20).

The third problem relates to the nature and quality of the interactions between forest owners, the forest authority (Forest Service) and private forest companies. While forest owners identified these interactions as an important source of essential funding for forest operations and management advice, they felt that the top-down nature of engagement and lack of constructive communication hinder the functions of (F3) knowledge diffusion and (F2) knowledge development, but also from a longer term perspective, (F1) entrepreneurial activities and the capacity of owners to co-innovate.

These three interlinked problems highlight the interventionist approach to forest policy and the top down nature of interaction with formal institutions focused on funding, compliance and inspection since the reorientation of state forest policy towards private afforestation in the 1980s (Fig. 1). This has promoted reliance among forest owners on intermediary service-providers (forest companies) to communicate on their behalf with the forest authority (Forest Service).

Hard institutions constitute the formal institutional mechanisms including, laws, regulations, standards and strategies that guide actors and their interaction in the sector (Wieczorek and Hekkert, 2012). The 'hard institutional' problems associated with deficiencies in the top down operation of afforestation schemes, compliance and regulation procedures has resulted in private owners who are typically inactive in the early management of their forests and who are passive receivers of expert advice, mainly through their forester or forest company whom they have mandated to establish the forest. Both forest owners and extension agents felt that this in turn feeds into the lack of forest culture among owners, whose initial planting decision may have been motivated by financial incentives and who have little recognition of the

strong market opportunities for their maturing crop and the return from investing in key management interventions such as thinning.

Forest owners and owner representative groups also spoke of the negative impact of information and knowledge asymmetries and opposing objectives (selective thinning vs volume maximisation) between forest owners and forest industry actors conducting harvest operations. They cited a small number of examples where some industry actors had taken advantage of owners' lack of knowledge to perform poor work with perverse management outcomes. Whilst all interviewees felt that the level of general awareness, knowledge and management capacity of owners was gradually increasing as private forests matured, helping to make such exploitative practices increasingly rare, all felt that any such examples had fostered a lack of trust between owners and commercial actors in the value chain.

'Strong networks' between incumbent players in the traditional timber market were also evident, particularly between the dominant roundwood supplier Coillte and the small number of large, efficient timber processors who buy the majority of roundwood. In general, the perception is of a myopic view of innovation among these incumbent stakeholders who are focused predominantly on process innovation in timber markets and roundwood supply chains. In this regard efficient harvest routines and chain of custody infrastructure for public forests have been developed over time to ensure efficient harvesting and compliance with certification standards and market requirements. Interviewees from the processing sector and some of those involved in a forest consultancy role recognised that the growing supply of uncertified roundwood from the private estate will soon challenge processors' ability to achieve the 30% limit for controlled (uncertified) wood, required to comply with Forest Stewardship Council (FSC) Chain of Custody Certification (CoC) standards. Unless similar standards and certification processes can be developed at scale for the private estate, the 30% controlled wood threshold will be reached in the near future if the private supply of roundwood continues to grow. Notwithstanding the focus of the interviews on forest and supply chain management, there was little discussion on the challenge of managing the forest resource with regard to alternative non-market objectives, in particular in relation to the role of carbon sequestration in climate change mitigation.

#### 4.2. Infrastructural problems blocking the reach and effectiveness of knowledge networks

Positive observations on network developments were made by interviewees across the value chain who highlighted a growing awareness within the sector of the need to better engage new forest owners through collaborative fora and formal networks to promote management capacity development. Successful examples include the establishment of a network of forest owner groups in recent years with the support of Teagasc and more recently, the Department of Agriculture, Food and the Marine (DAFM), exchequer funded, peer-to-peer forest owner discussion group scheme, the forestry Knowledge Transfer Group (KTG) scheme, facilitated by professional foresters (COFORD, 2015).

Recent exploratory research (Stoettner and Ní Dhubháin, 2017) highlights the positive contribution of forest owner groups to network-building and suggests that they are at least as effective in (F3) knowledge diffusion and (F2) development and practice change as traditional means of public forestry extension. In line with international studies of non-industrial private forest owner (NIPF) cooperation (Kittredge, 2005) forest owners networks and cooperation in Ireland vary in their intensity, type of cooperation, and level of organisation. Interviews with the forest owners that participate in these groups along with the extension agents and private forest company employees who facilitate these groups, confirm that groups vary significantly in their structure, national spatial coverage and stage of development, from informal discussion groups to established businesses with their own management, marketing and processing capacity. Deficiencies in the knowledge



infrastructure are reflected in a low level of participation, with only 15% of forest owners currently registered as members of forest owner groups (Stoettner and Ní Dhubháin, 2017). The lack of national coverage and capacity of these groups undermines the potential for (F3) knowledge diffusion and (F2) development among forest owners.

Interviews with contractors, management intermediaries, forest companies and extension agents indicate that there is also a considerable cohort of hard-to-reach 'non-engagers', i.e. forest owners who do not participate in formal knowledge networks and do not actively engage in forest management. These non-engagers reflect both 'actor presence' and 'actor capabilities' problems. Furthermore, by their nature it is difficult to identify these non-engagers and there remains a gap in our understanding of who these owners are, what their objectives are and what hinders their engagement with the forest innovation system.

The problem of hard-to-reach owners is exacerbated by the need for increased competency and investment in monitoring and evaluation within the forest sector institutions, which is an additional and compounding 'actor capabilities' problem. Development of theory-driven reflexive competencies and practices at all stages of extension, from intervention design to ex-post evaluation of outcomes and impact is thus required for better-targeted Knowledge Transfer interventions. This is reflected in the literature which calls for the need for complexity-aware evaluation of programmes that intervene in complex systems such as the forest sector (Douthwaite et al., 2003; Stame, 2004; van Mierlo et al., 2010). In particular, impact evaluation provides a reflexive learning tool to enable the interrogation of impact pathways for traditional and group extension interventions. Accordingly, theory-driven evaluation techniques enable extension to explicitly assess whether the target of an intervention is being reached, how the process of (F3) knowledge diffusion, (F4) development and longer term practice change occurs, and to reflect and learn to improve future interventions (Secco et al., 2019).

#### 4.3. Rigid institutions and policy blocking co-innovation and sustainable transition

With a maturing private estate (Fig. 1), the forest sector has only recently switched its focus from private afforestation to the development of the private value chain and wood mobilisation. However, historic institutional challenges that arose in the 1980s can be seen to both parallel and in themselves contribute to the current private mobilisation challenge. During the 1980s, State forests planted from 1950 onward (Fig. 1) were approaching harvest age, necessitating a shift in policy and industry focus from state afforestation to the development of a value chain for State roundwood (Neeson, 1991). Based on the recommendation of a review group of the forest sector (DFF, 1985) the state forestry board (Coillte) was established in 1988 with a remit to manage the public forest estate on a commercial basis. At that time it was advised that the sale of roundwood and wood products on a commercial basis could not be done within the institutions of the Civil Service due to a lack of commercial competencies (DFF, 1985).

In a present-day parallel, interviewees across the value chain raised a systemic weakness and 'hard institutional' problem in relation to the current lack of commercial focus and capacity within the Forest Service in general. Farm forest owners and management company interviewees were critical of the process of engagement with government institutions, the Forest Service and other state consultative bodies involved in the assessment procedures for forest harvest licensing and road grant and access applications. Significant administrative delays in processing applications, an over-burdened forestry appeals process and the increasing cost of compliance to meet forest standards were seen as an important barrier to (F1) entrepreneurial activities, in particular, the harvesting and marketing of roundwood and, consequently, wood mobilisation. While the industry actors and large saw-millers in particular have much less direct interaction with government agencies, they were concerned about the impact of blockages in processing license applications on the supply of roundwood from private and state forests. They also voice

frustrations with the Forest Service in relation to the development of practical systems of phytosanitary certification in the face of emerging market challenges and the UK's decision to withdraw from the European Union (Winkel and Derks, 2016).

Government agencies involved in appropriate assessment processes (DAFM, 2012) have a regulatory and inspectorate role in overseeing the application of increasingly stringent standards associated with sustainable forest management (SFM). With regulation and inspection as their primary function, these government agencies (Forest Service and consultative bodies) are sometimes viewed as a barrier to innovation rather than a promoter in the wood value chain. Among industry and forest owners, there is a perception that these agencies lack the commercial competencies and understanding required to engage practically in the promotion of (F1) entrepreneurial activities.

Forest Service (FS) inspector interviewees saw their role as ensuring compliance with forest standards rather than forestry promotion, advisory or forest development. In this role they felt that they need to keep professional distance from private forest owners whose forests they are required to inspect for compliance with regulations. FS inspectors have little direct contact with forest owners but instead typically communicate on management requirements through newsletters, intermediary management service providers, private consultants/foresters, and forest management companies. Direct communication between inspectors and forest owners only really happens at times of inspection and when sought by the forest owner. Forest service staff felt that the administrative backlog in approving felling license applications and afforestation applications was being exacerbated by insufficient resourcing (staffing numbers and staffing capacity) of consultative bodies involved in the appropriate assessment procedures for forestry applications. Inspectors also felt that they were coming under pressure to make assessments based on increasingly technical and complex compliance requirements, which in some cases are outside the scope of their competencies and thus increasingly difficult to manage.

On a positive note, industry interviewees highlighted the constructive contribution of Enterprise Ireland (EI), the government-funded organisation responsible for the development and growth of Irish enterprises in world markets, in working successfully in partnership with industry to fund R&D projects and grow export sales in the UK, thus supporting (F1) entrepreneurial activities and (F5) market formation functions. In the face of the Brexit challenge, EI is positively viewed as a strategic support in defending market share for Irish wood exports and in identifying other new markets outside the UK.

Interviewees in the enterprise domain highlighted barriers caused by the rigid nature of institutional structures and their inability to adapt to stakeholder feedback. This was particularly evident with blockages and administrative delays in appropriate assessment procedures for grant applications and licences for forest operations and delays caused by a backlog of appeals. Furthermore it was felt that national forest innovation support policies are lacking and/or relatively uncoordinated, with interviewees highlighting examples where forest policy was found to be competing with other land use policies and agriculture in particular, e.g. where participation in afforestation and agri-environment schemes are mutually exclusive. While these can be categorised as 'hard institutional' problems they also reflect institutional reflexivity and coordination problems, two forms of 'transformational problem' as defined by Weber and Rohrer (2012), which reflect on the overall functioning of a sectoral innovation system and its ability to adapt to support major transitional challenges.

In the context of addressing the major societal challenges and in particular climate change, systems approaches to innovation in forest policy have a key role in strategically transitioning the forest sector towards more sustainable systems of innovation, production and consumption (Weber and Rohrer, 2012). Shifting rationale for policy intervention in the Irish private forest sector is reflective of the growing importance of cross-sectoral sustainability challenges. Initially incentives for private afforestation were based on compensating forest

owners for the market failure associated with the long-time horizon before realising a market return, with a view to increasing forest cover on private lands and reducing import dependence on roundwood (Neeson, 1991). Over time the policy rationale for continued support of afforestation grants and premia supports has shifted beyond timber production to the delivery of ecosystem services, particularly towards carbon sequestration given Ireland's national binding climate change targets (DAFM, 2014; Duffy et al., 2020). In this context it is informative that societal stakeholders such as interest groups, NGOs and charities were perceived by all interviewees as playing an increasingly important role in influencing the institutional setting and societal expectations for forest management through a number of functions: (F4) creation of legitimacy, (F6) resource mobilisation and (F7) guidance of the search.

The analysis also suggests that 'hard institutional' and 'interactions' failures exist relating to deficiencies in the capacity of the formal institutions to engage directly with the range of stakeholders and to facilitate constructive communication among these societal stakeholders and the wider community. This is negatively impacting on the ability of the sector to both come together to agree on a vision for innovation (F4 - guidance of search), and to continue to promote the positive economic and environmental contribution of the sector to rural agrarian communities with little tradition of farm forestry (F7 - creation of legitimacy). This feeds into 'soft institutional' problems reflected in the contested narrative of the contribution of the commercial forest sector between traditional sectoral stakeholders and those viewed as external societal stakeholders and interest groups with seemingly divergent values for forest management (Duesberg and Ní Dhubháin, 2019).

'Soft institutions' refer to the informal set of habits, routines, and shared values/culture built up over time and through repetition. Emerging societal stakeholders are increasingly influential in defining a social license to operate in forestry (Toppinen et al., 2016). This is consistent with the observations of Duesberg and Ní Dhubháin (2019) and Ní Dhubháin et al. (2009) who highlight that while state-owned, plantation forests in Ireland have been traditionally managed under a relatively intensive regime, this is negatively perceived by some societal groups, emerging forest sector stakeholders and coalitions who value other ecosystem goods and services such as recreation and environmental services ahead of wood production. More recently, Duesberg and Ní Dhubháin (2019) showed that management disturbances such as large clearfell harvesting operations or extensive localised afforestation are likely to lead to growing social conflict, a more negative perception of forestry and to act as a barrier to intensification of management, harvesting and future timber mobilisation.

## 5. Discussion

### 5.1. Recent sectoral developments

Since interviews were conducted for this study, two sectoral reports were commissioned by the Department of Agriculture Food and the Marine (DAFM) to address administrative delays in the forest licensing process, the MacKinnon (2019) and O'Hara (2021) reports. Both these sectoral reports identified similar institutional deficiencies constraining wood mobilisation to those identified in this study.

The Mackinnon (2019) report is an external review of the Forest Service licensing system which provided a suite of recommendations to address some of barriers to afforestation and resource mobilisation. While the implementation of the report was committed to under the Programme for Government and some resources were directed towards addressing administrative deficiencies, progress has been limited and inhibited partly by wider geopolitical (Brexit) and public health (Covid-19 pandemic) considerations (O'Hara, 2021). The subsequent deepening crisis in the licensing process for harvesting operations experienced in 2020 "threatened the ongoing operation of the forestry sector as a whole" and led to the development of a second report aimed at

progressing and guiding the implementation of the Mackinnon Report (O'Hara, 2021, p. 5).

These reports acknowledge that prioritisation criteria for larger sites, aimed at "mitigating the most immediate threat to the processing sector" (O'Hara, 2021, p.5), discriminate against small private forest owners, extending the delay in processing their applications, at a time when supply is constrained and timber prices are high. This further promotes a negative institutional interaction for the very cohort of private owners who have the potential to plant more forests and increase roundwood supply but who are increasingly disaffected by administrative hold-ups.

While recommendations for planning grants to address equity issues in environmental reporting for forest licences have been proposed (O'Hara, 2021), and would address administrative costs, the inclusion of forest owners in the design of institutional procedures is required. While future forest policies, initiatives and regulations must be developed in the context of emerging EU directives and strategies for land use, the design and operation of these national institutional frameworks should be conscious of the specific challenges and constraints faced by non-industrial private forest owners (NIPF) if new policies are to be effective in engaging them.

Despite the role of government in commissioning these reports and the suggested actions, weaknesses in the structure of the formal institutional setting persist, which over time have contributed to blocking mechanisms. These systemic problems are a legacy of the interventionist top-down policy for private forestry in Ireland which commenced in the mid-1980s (Neeson, 1991). While formal institutions acknowledge the need to foster a culture of collaboration and networks within the sector (through incentives to support owner and discussion groups), interviewees feel that the same culture of inclusiveness and co-learning does not appear to be evident in institutional communications with private small scale forest owners, value chain actors and new emerging societal stakeholders. Interviewees across actor domains also perceived that there has been a lack of leadership and capacity among formal institutions and traditional forestry stakeholders to meaningfully engage with emerging stakeholders and coalitions who value other ecosystem goods ahead of wood production.

The diagnosis of systemic problems and blocking mechanisms in this study identifies how (functions) and why (systemic problem and underlying causal mechanisms) the forest sector innovation system is not performing efficiently in some domains. It also points to areas where intervention is required and identifies knowledge gaps which require further investigation in order to improve system functioning. The subsequent discussion addresses these findings by suggesting potential actions aimed at enhancing the coordinated performance of the IS.

### 5.2. Addressing policy coordination and reflexivity

The analysis of the forest innovation system highlights deficiencies in the capacity of the formal institutions to engage with stakeholders directly, to facilitate communication among stakeholders and the wider community and to be an inability to bring the sector together to agree on a vision for innovation. While a number of separate initiatives and projects targeted at improving specific aspects of system functioning were evident, the sector is not cohesive and is perceived to lack overall guidance and coordination.

Many interviewees particularly those from the enterprise domain believe that national forest innovation support policies are lacking and/or relatively uncoordinated, highlighting examples where forest policy was found to be in competition with other land use policies. Thus while forest policy documents claim to be well coordinated with other sectors and reflective of "society's changing demands" (COFORD, 2018a, p.1; DAFM, 2014), feedback from interviewees suggests that effective coordination of policies is lacking. Furthermore there is little recognition of innovation as a policy goal beyond traditional sectoral process and product innovation to "assist product development and forestry management" (DAFM, 2014, p46).

From this perspective, interviewees from the intermediary and enterprise domains highlighted the importance of organisations that fulfil an ‘innovation intermediary’ role (Teagasc, Enterprise Ireland and COFORD) who facilitate linkages between the users and producers of innovation. A number of interviewees across actor domains also proposed the need for an independent overarching third-party organisation to facilitate the formation and maintenance of innovation networks and innovation systems perspectives across the sector. Such an organisation could fulfil the strategic sectoral role of ‘innovation intermediary’ by providing information to support potential collaborations, brokering transactions between parties, acting as a mediator for collaborating parties, helping to find advice, funding, support for collaborations, and collective priority setting, as suggested by Howells (2006). While there are examples of such organisations successfully operating dedicated innovation intermediary roles in the agriculture sector such as AHI (Animal Health Ireland) (Devitt et al., 2013) they are less evident in the forest sector in Ireland.

The concept of a ‘Forest Council’ which would act as an innovation intermediary to “oversee policy implementation and as an overall co-ordination body for on-going policy development”, is not new (DAFM, 2014, p.35). Previous reviews of forest sector policy (Bacon and Associates, 2004; Malone, 2008, p.16) have highlighted the need for an overarching forest sector body “to generate a stronger forest culture, represent the totality of views in the sector”. Indeed a key recommendation of the most recent forest sector policy and strategy ‘Forests, products and people - Ireland’s forest policy – a renewed vision’ (DAFM, 2014) was the establishment of a Forest Council based on the COFORD Council’s model of collaboration with Department of Agriculture, Food and the Marine and the wider forest and timber sector. Developing this model of public/private partnership through a new sectoral intermediary could provide a collaborative platform for a reflexive policy process “adaptive to changing circumstances” (COFORD, 2018a, p.5).

It is apparent from the analysis that significant reflexivity and co-ordination problems exist in the policy setting institutions. These are two forms of transformational problems as defined by Weber and Rohracher (2012) which reflect on the overall functioning of a sectoral innovation system and its ability to achieve collective priority setting and adapt to support major transitional challenges. To address these challenges and take account of potentially competing or complementary policy drivers requires institutional innovation along with further research to develop practical policy evaluation tools. In particular, a multi-level policy perspective could be developed by extending the analytic framework presented in this study to explicitly take account of how the objectives of multiple land-use policies impact system functioning. This would be a particularly useful approach to facilitate the “shared national approach to forestry” strategy setting and policy formulation currently seen as lacking (O’Hara, 2021, p.15). Similar extended frameworks have been developed to address strategic, long-term needs of goal-oriented transformative change policy in agricultural contexts (Lamprinopoulou et al., 2014; Turner et al., 2016).

### 5.3. Suggestions for process innovation

In contrast to other State institutions in the forest sector, there has been a significant advancement in commercial competencies within Coillte. Since its establishment in the 1980s, and in line with its commercial remit, it has successfully developed forest management systems and business networks. Some foresters operating in the private sector suggest that deficiencies in the private supply chain infrastructures (infrastructural problems) could be addressed by adopting a number of Coillte’s harvesting, transport and sales systems. Such process innovation in the private sector could provide improved efficiency, price transparency and manned loading points, thus contributing to resource mobilisation within the sector. In particular, Coillte’s timber sales system is viewed as particularly effective and efficient, as Coillte has the scale and capacity to achieve industry agreement and to employ

monitoring personnel at delivery points. In this context it was proposed by some interviewees that there is a policy rationale to leverage Coillte’s harvesting and marketing experience to develop some public service functions, such as the facilitation of a standard system for timber measurement and removals and health and safety systems for the private sector.

### 5.4. Suggestions for fostering network development

Addressing structural weaknesses in forest sector knowledge infrastructure requires continued investment in extension resources to facilitate the development of forest owner groups. Given the low levels of forest owner participation in owner groups and reliance on professional service providers, alternative mechanisms could be explored to increase private owner engagement and facilitate collective approaches to the growing need for certification of private forests.

Participation in peer-to-peer forest owner discussion groups facilitated by professional foresters is currently financially incentivised through the forest knowledge transfer group scheme (KTG), similar to other agriculture sectors. However unlike Irish farming KTG schemes, forest owners are limited to one year of participation. Greater resources to allow continued participation in this scheme would contribute to stronger network development and the scheme goals of owner capacity development and ultimate wood mobilisation. An alternative potential mechanism to foster network development would be to make participation in a local owner group compulsory after the crop reaches a certain stage of maturity. A similar approach obliges owners to complete a forest management plan template when their crop reaches 12 years old or forego remaining subsidy payments.

To improve the targeted delivery of extension services across the range of forest owners, extension providers need to invest resources to develop planning, monitoring and evaluation competencies. Improved competency in theory-driven planning, monitoring and evaluation techniques (Douthwaite et al., 2003) enables extension agents to better plan knowledge transfer interventions and to subsequently assess and address whether the target of an intervention is being reached and how the process of knowledge diffusion, development and longer term practice change or impact is being met.

From a research perspective, the effectiveness of both traditional and group extension interventions can also be assessed through theory-driven evaluation. This would enable an assessment of the level to which extension interventions currently incorporate principles of co-innovation and collaboration at all stages and whether they adequately take account of the complexity of innovation processes within the forest sector innovation system (Douthwaite and Hoffecker, 2017).

Social network analysis (SNA) techniques can be used to further inform the stakeholder analysis performed in this study by identifying central and peripheral actors in the forest network. Taking a wider sectoral perspective to investigate the role of forest networks in decision making and resource mobilisation would add to the contribution of Stoettner and Ní Dhubháin (2017) which looked solely at networks among forest owners. While this study identified Teagasc forest development officers as performing an ‘innovation intermediary’ role by facilitating interactions between forest owners and other sectoral actors with whom they are otherwise lacking access, SNA techniques allow measures of brokerage to be empirically analysed (Knoke and Yang, 2008). The identification of intermediaries is important for long-term resource management planning as they bring together disconnected actors/actor groups, supporting co-innovation by bringing diversity and new ideas to the network (Prell et al., 2009; Wasserman and Faust, 1994).

## 6. Conclusions

Within the past century, Ireland has witnessed a significant increase

in forest cover from just over 1% at the time of the formation of the Irish State, to the current level of 11.2% of land area. In this period the sector has achieved considerable success having evolved from a reliance on imported timber and state afforestation, to private largely farmer-led planting on agricultural land and the development of an efficient, export-oriented processing sector.

The rapid nature of this development brings its own challenges and the sector is entering a new era as privately owned forests planted since the 1980s start to reach maturity and require active management. The owners of these forests have little experience of forest management, thus uncertainty surrounds both their intentions and capacity to actively manage these forests. Other challenges lie within the value chain in which the state was historically the primary roundwood supplier and which now has to adapt to accommodate a large number of diverse small-scale owners. While there has been a growing emphasis on developing knowledge and forest management capacity and many public and private sector institutions have developed a range of supports and structures for new forest owners (e.g. forest establishment and management contracting/consultancy, advisory, education and social networks, forest owner groups), there is now a growing challenge to harness and mobilise the private forest resource. Thus while there is strong potential to increase roundwood supply should barriers to private forest harvesting be overcome, this not only challenges the management capacity of inexperienced forest owners but the collective capacity of the wider sector to innovate and address a range of overarching and interconnected environmental, infrastructural and institutional constraints.

This study provides insights to these wood mobilisation constraints through a systemic analysis of the combined structural and functional problems impacting the development of innovation across the Irish forest sector from 'new' forest owners to wood processors. In response to these innovation challenges this study suggests a number of recommendations taking account of the inherent complexity in the system. The combined structural-functional approach taken here goes further than previous forest sector innovation system studies by linking systemic problems to particular functions. It also identifies the shared underlying issues that influence the performance of several interacting functions and provides suggestions for systemic instruments that enhance the coordinated performance among these functions. This is achieved by identifying where certain combinations of systemic problems, 'blocking mechanisms' are linked to each other as a result of historical patterns of practice, prevailing culture, attitudes, rules. This approach adds value for the Irish forest sector innovation systems as it transitions to a new stage in its development.

The study shows that the Irish forest sector is at an important stage of development; the private forest estate is young, its owners are new to forest management, the private forest value chain is underdeveloped and the overarching innovation system is immature in terms of its capacity to support innovation across the sector. The results of the innovation systems analysis identify the following interconnected systemic problems or 'blocking mechanisms' which have developed over time through persistent deficiencies in the formal institutional structures and policy framework, hindering co-innovation: (i) weak networks blocking capacity development of new forest owners; (ii) infrastructural problems blocking the reach and effectiveness of 'knowledge networks'; and (iii) rigid institutional structures and policy blocking co-innovation and sustainable transitions.

While multiple constraints to innovation at different levels are

identified, interviewees recognised the need to work together to develop a well-functioning private wood value chain. While there appears to be a re-orientation of policy towards private resource mobilisation and a growing market orientation as private forests mature, this study identifies a number of research and policy gaps along with coordination and infrastructural deficiencies which require further investment to promote co-innovation in the sector:

- Further investment in extension resources is required to facilitate the development of a national network of owner groups and continued funding for discussion/producer groups.
- Investment in extension resources to develop monitoring and evaluation competencies to improve the design and delivery of targeted services across the range of forest owners.
  - In particular knowledge gaps should be addressed in relation to the profile of 'non-engager' forest owners and how they compare to those engaging with formal extension interventions.
- Identification of sectoral 'innovation intermediaries' through SNA techniques is required to aid long term resource management planning.
- Development of policy evaluation tools which can take account of potentially competing or complementary policy drivers.
- Development of an independent overarching third-party organisation to facilitate the formation and maintenance of innovation networks and innovation system perspectives across the sector.

To our knowledge this is the first application of the 'coupled structural-functional' framework (Wieczorek and Hekkert, 2012), to a wood value chain. While the innovation system analysis presented here focuses on the Irish forest sector, the nature of the innovation challenges facing the forest sector across many European member states are comparable. Thus both the analytical structure and the findings presented here are likely to be useful in different European contexts.

#### Author statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication.

#### Declaration of Competing Interest

None.

#### Acknowledgements

This work was completed as part of the FOROWN (Irish forest owners: The role of knowledge transfer and social networks) research project funded by the Irish Department of Agriculture, Food and the Marine (DAFM) through a COFORD research grant (grand number 15/C/684). The authors thank all interviewees who agreed to participate and gave of their time.

#### Appendix A. Identification of 'systemic problems' in the Irish Forest Sector Innovation System



Categories of problems/merits	Research domain	Enterprise domain	Influencing domain	Intermediary domain
Actor capabilities ( <i>Key skills or competencies required to contribute to IS functioning</i> )	<ul style="list-style-type: none"> <li>Limited stakeholder interaction</li> <li>Limited competencies in impact assessment/evaluation of research activities</li> </ul>	<p>No tradition of farm forestry and management and associated lack of management and operational skills</p> <ul style="list-style-type: none"> <li>Little experience and expertise in harvest operations within some forest companies</li> </ul>	<ul style="list-style-type: none"> <li>Limited impact assessment/evaluation</li> <li>Limited commercial competencies within State Forest Service</li> <li>Limited knowledge of forestry among state consultative bodies involved in licensing</li> </ul>	<ul style="list-style-type: none"> <li>Teagasc – Cross sectoral and strong integrated organisational capacity</li> <li>Limited competencies in impact assessment/evaluation of extension &amp; education initiatives</li> </ul>
Infrastructural problems ( <i>Requiring strategic investment</i> )	<ul style="list-style-type: none"> <li>Integrated public knowledge system combining research, education/training extension</li> <li>Low staff numbers in some functions</li> </ul>	<ul style="list-style-type: none"> <li>IT and sales systems more developed for State roundwood supply channels</li> <li>Insufficient training infrastructure and funding</li> <li>Lack of investment in haulage infrastructure and poor uptake of technology grants, e.g. variable tyre inflation system</li> <li>Small, fragmented, inaccessible private sites</li> </ul>	<ul style="list-style-type: none"> <li>Poor internal and public road network challenging resource mobilisation</li> <li>Limited availability of funding for community-led rural development projects (LEADER programme)</li> </ul>	<ul style="list-style-type: none"> <li>Low staff numbers and limited training facilities and infrastructure for forest operatives</li> </ul>
Interaction or network Problems  - Weak Network Problems ( <i>Limited interaction between actors</i> )	<ul style="list-style-type: none"> <li>Limited direct interaction and collaboration with enterprise domain, industry and forest owners</li> </ul>	<ul style="list-style-type: none"> <li>Limited interaction of industry with primary producers and research domain</li> <li>Limited geographic coverage of forest owner groups</li> </ul>	<ul style="list-style-type: none"> <li>Limited interaction and communication between State Forest Service and forest owners</li> <li>Limited coordination between Forest Service at a national level and Local Planning Authorities at a local level</li> </ul>	<ul style="list-style-type: none"> <li>Extension service viewed by private owners as “honest brokers” effective in building and facilitating networks</li> <li>Limited interaction of extension services with industry</li> </ul>
Interaction or network Problems  - Strong Network Problems ( <i>dominant relationships hampering interaction with outside actors</i> )	<ul style="list-style-type: none"> <li>Dominant relationship with Forest Service as key funding body (Scope of research limited by need to win State research grants)</li> </ul>	<ul style="list-style-type: none"> <li>Historic industry focus on development of public (State) roundwood value chain and relationship with State forest company (Coillte) to the detriment of private roundwood value chain development</li> </ul>	<ul style="list-style-type: none"> <li>Lack of direct communication channels between forest owner and Forest Service who instead communicate through intermediary service providers</li> </ul>	
Institutional Problems  - Hard Institutional Problems ( <i>Formal rules and regulation</i> )	<ul style="list-style-type: none"> <li>Limited responsiveness of research resulting from funding mechanisms</li> <li>Narrow focus on metrics of research quality</li> </ul>	<ul style="list-style-type: none"> <li>Limited responsiveness of owners resulting from structure of funding mechanisms, mandating of grant payments to forest companies</li> <li>Complicated, expensive forest certification procedures for small-scale private owners</li> </ul>	<ul style="list-style-type: none"> <li>Strong emphasis on rigid inspectorate and administrative roles</li> <li>Administrative blockages in approving felling licensing and forest road applications</li> <li>Deficiencies in planning process for forest entrances and access to public roads</li> </ul>	
Institutional Problems  - Soft institutional Problems ( <i>informal rules of conduct and interaction</i> )	<ul style="list-style-type: none"> <li>Greater focus on research outputs and less on communication</li> </ul>	<ul style="list-style-type: none"> <li>Lack of forest culture among forest owners and rural communities</li> <li>Forest owners perceived as passive receivers of expert management advice through professional forester or forest company whom they employ</li> </ul>	<ul style="list-style-type: none"> <li>Lack of acceptance and knowledge of commercial forestry among rural agricultural communities</li> </ul>	<ul style="list-style-type: none"> <li>Positive perception of extension agents as innovation intermediaries, facilitating knowledge translation in networks</li> <li>Limited acceptance of forestry as viable alternative land use outside forestry specialist staff</li> </ul>

**Appendix B. Systemic problems impacting functions of the Irish Forest Innovation System**

System function	Structural element	Description
Entrepreneurial activities	Actors	<ul style="list-style-type: none"> <li>Significant product and process innovation evident within an efficient, modern processing (sawmilling) industry since previous global economic downturn.</li> <li>Limited evidence of entrepreneurial competency and activities among other key actors particularly among new forest owners</li> <li>Lack of entrepreneurial capacities in research organisations, State Forest Service</li> </ul>
	Interaction	<ul style="list-style-type: none"> <li>Limited examples of research interacting with industry to experiment in the development of new products or processes</li> <li>Limited interaction of owners with downstream users to promote entrepreneurial activities</li> </ul>
	Institutional	<ul style="list-style-type: none"> <li>Strong focus on entrepreneurial activities in State forest company (Coillte) in line with commercial remit</li> <li>Limited examples of investment in partnership between publicly funded research and enterprise</li> <li>Successful partnership between State body responsible for the development of Irish enterprises in world markets ‘Enterprise Ireland’ and industry (R&amp;D funding targeted at export development)</li> </ul>
Knowledge development	Actors	<ul style="list-style-type: none"> <li>State Forest Service is not directly involved in knowledge development function</li> <li>Missing actor through loss of research function within State owned forest company</li> </ul>
	Interaction	<ul style="list-style-type: none"> <li>Lack of active communication and collaboration between enterprise actors to facilitate co-learning</li> </ul>
	Institutional Infrastructure	<ul style="list-style-type: none"> <li>Linear metrics of research quality too rigid to foster collaboration</li> <li>Lack of funding for collaborative knowledge development in research projects</li> <li>Weaknesses in the formal training system for forest operatives (progress evident – investment in harvest simulator and training)</li> </ul>

(continued on next page)

(continued)

System function	Structural element	Description
Knowledge diffusion	Actors	<ul style="list-style-type: none"> <li>• Integrated Teagasc model combining research, extension and education</li> <li>• Teagasc extension agents viewed as having a key role as practical translators of technology</li> <li>• Limited experience and capacity of forest owners to engage with new practices</li> <li>• Little role for forest consultants and service intermediaries in knowledge diffusion (focus on traditional service provision with owners, KTG scheme an exception)</li> </ul>
	Interaction	<ul style="list-style-type: none"> <li>• Limited interaction between industry and research associated with supply push model of research delivery</li> <li>• Limited interaction between forest owners and downstream industry/processers</li> <li>• Significant cohort of 'non-engaging' forest owners who don't participate in knowledge networks</li> </ul>
	Institutional	<ul style="list-style-type: none"> <li>• No role for State Forest Service in knowledge diffusion (limited to regulatory and inspectorate role)</li> <li>• Structure of research grants placing disproportionate focus on metrics of knowledge development to the detriment of diffusion</li> </ul>
	Infrastructure	<ul style="list-style-type: none"> <li>• Limited resources dedicated by industry to engaging with forest owners and wider public outreach</li> </ul>
Market formation	Infrastructure	<ul style="list-style-type: none"> <li>• Successful development of UK export markets for sawmilling products</li> <li>• Industry focus on development of traditional construction markets and less of development of novel value added markets (e.g. engineered wood products)</li> </ul>
	Interaction	<ul style="list-style-type: none"> <li>• Limited interaction of industry with research on novel products development</li> </ul>
	Institutional	<ul style="list-style-type: none"> <li>• Lack of strategy coherence among State and semi-State bodies to support new renewable markets</li> <li>• Positive supports for new international market development through Enterprise Ireland</li> <li>• Deficiencies in the certification process for private forests remain (progress has been made with pilot group certification initiative)</li> </ul>
	Infrastructure	<ul style="list-style-type: none"> <li>• Lack of resources and supports to establish alternative markets among small scale forest owners</li> </ul>
Guidance of search	Actors	<ul style="list-style-type: none"> <li>• Growing awareness among industry actors of the importance of communication activities aimed at shaping future trajectories for industry</li> </ul>
	Interaction	<ul style="list-style-type: none"> <li>• Formal Industry working groups active in creating forums of communication across value chains and informing policy and sectoral development</li> <li>• Poor communication between established industry actors and with emerging private sector, challenges collaborative priority-setting</li> <li>• Limited industry-research and co-ordination of innovation agendas and activities</li> </ul>
	Institutional	<ul style="list-style-type: none"> <li>• Top-down government policy important to the functioning of innovation, but their role is perceived as too focused on regulatory aspects instead of active engagement with enterprise</li> </ul>
	Infrastructure	<ul style="list-style-type: none"> <li>• Lack of funding and infrastructures to support communication, relationships and consensus-building across disparate actors</li> </ul>
Resource mobilisation	Infrastructure	<ul style="list-style-type: none"> <li>• Examples of successful collaboration between industry and training groups to win funding and tackle deficiencies in the training system</li> </ul>
	Institutional	<ul style="list-style-type: none"> <li>• Competition among industry for resources to support innovation agendas</li> </ul>
	Infrastructure	<ul style="list-style-type: none"> <li>• Poor physical road infrastructure undermining the access, harvest and transport of wood material from small fragmented private forests</li> <li>• Less developed private harvesting, transport and sales systems compared to State forest company (Coillte)</li> </ul>
Creation of legitimacy	Actors	<ul style="list-style-type: none"> <li>• Underdeveloped voice of private farm forest sector (beginning to emerge though shared narrative of positive local experiences of experimentation in management and collaborative arrangements)</li> </ul>
	Interaction	<ul style="list-style-type: none"> <li>• Little tradition of interaction and engagement between forest industry and rural communities (in comparison to agriculture)</li> </ul>
	Institutional	<ul style="list-style-type: none"> <li>• Competing priorities for the sector between industry and government</li> <li>• Negative perceptions of commercial forestry among portion of the rural community</li> </ul>

## References

- Arnold, E., Bell, M., 2001. Some new ideas about research for development. In: *Partnerships at the Leading Edge: A Danish Vision for Knowledge, Research and Development*. Ministry of Foreign Affairs/Danida, Copenhagen, pp. 279–319. Report of the Commission on Development Related Research Funded by Danida.
- Bacon, P., Associates, 2004. A Review and Appraisal of Ireland's Forestry Development Strategy. Final Report. Report commissioned by the Department of Agriculture and Food (DAF), Dublin.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. *Res. Policy* 37 (3), 407–429. <https://doi.org/10.1016/j.respol.2007.12.003>.
- Breschi, S., Malerba, F., 1997. Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. In: Edquist, C. (Ed.), *Systems of Innovation: Technologies, Institutions and Organizations*, pp. 130–156.
- Buttoud, G., Kouplevatskaya-Buttoud, I., Slee, B., Weiss, G., 2011. Barriers to institutional learning and innovations in the forest sector in Europe: markets, policies and stakeholders. *Forest Policy Econ.* 13 (2), 124–131. <https://doi.org/10.1016/j.forpol.2010.05.006>.
- Clinch, J.P., 2000. Assessing the social efficiency of temperate-zone commercial forestry programmes: Ireland as a case study. *Forest Policy Econ.* 1 (3–4), 225–241. [https://doi.org/10.1016/S1389-9341\(00\)00029-0](https://doi.org/10.1016/S1389-9341(00)00029-0).
- COFORD, 2015. Mobilising Ireland's Forest Resource (COFORD Wood Mobilisation Industry Working Group).
- COFORD, 2018a. Forest Policy Review Group Report on 'Forests, Products and People -Ireland's Forest Policy – A Renewed Vision' (2014). A Report on Policy Implementation with Recommendations. Department of Agriculture, Food and the Marine, Dublin.
- COFORD, 2018b. Mobilising Ireland's Forest Resource Meeting the Challenges (COFORD Wood Mobilisation and Production Forecasting Group).
- DAFM, 2012. Forest Service Appropriate Assessment Procedure Information Note March 2012.
- DAFM, 2014. Forests, Products and People Ireland's Forest Policy – A Renewed Vision. Department of Agriculture, Food and the Marine (DAFM), Dublin.
- DAFM, 2017. The Third National Forest Inventory Republic of Ireland Main Findings. Forest Service, Department of Agriculture, Food and the Marine, Co. Wexford.
- DAFM, 2020. Forest Statistics Ireland 2019. Department of Agriculture, Food & the Marine. Co. Wexford.
- Devitt, C., McKenzie, K., More, S.J., Heanue, K., McCoy, F., 2013. Opportunities and constraints to improving milk quality in Ireland: enabling change through collective action. *J. Dairy Sci.* 96 (4), 2661–2670. <https://doi.org/10.3168/jds.2012-6001>.
- Devlin, G., Klvač, R., 2014. How technology can improve the efficiency of excavator-based cable harvesting for potential biomass extraction — A Woody productivity resource and cost analysis for Ireland. *Energies* 7 (12), 8374–8395. <https://doi.org/10.3390/en7128374>.
- Devlin, G.J., McDonnell, K., Ward, S., 2008. Timber haulage routing in Ireland: an analysis using GIS and GPS. *J. Transp. Geogr.* 6 (1), 63–72.
- DFP, 1985. Review Group on Forest. Report to the minister for fisheries and forestry. Department of Fisheries and Forestry, Dublin.
- Douthwaite, B., Hoffecker, E., 2017. Towards a complexity-aware theory of change for participatory research programs working within agricultural innovation systems. *Agric. Syst.* 155, 88–102. <https://doi.org/10.1016/j.agsy.2017.04.002>.
- Douthwaite, B., Kuby, T., van de Fliert, E., Schulz, S., 2003. Impact pathway evaluation: an approach for achieving and attributing impact in complex systems. *Agric. Syst.* 78 (2), 243–265. [https://doi.org/10.1016/S0308-521X\(03\)00128-8](https://doi.org/10.1016/S0308-521X(03)00128-8).
- Duesberg, S., Ní Dhubháin, Á., 2019. Forest intensification in Ireland: developing an approximation of social acceptability. *Land Use Policy* 85, 368–386. <https://doi.org/10.1016/j.landusepol.2019.03.028>.
- Duesberg, S., Ní Dhubháin, Á., O'Connor, D., 2014. Assessing policy tools for encouraging farm afforestation in Ireland. *Land Use Policy* 38, 194–203. <https://doi.org/10.1016/j.landusepol.2013.11.001>.
- Edquist, C., 2013. *Systems of innovation: technologies, institutions and organizations*. Routledge.
- Edquist, C., Johnson, B., 1997. Institutions and organisations in systems of innovation. *Systems of Innovation—Technologies, Institutions and Organizations*. Pinter, London.
- Edwards, D., Jay, M., Jensen, F.S., Lucas, B., Marzano, M., Montagné, C., Peace, A., Weiss, G., 2012. Public preferences across Europe for different forest stand types as sites for recreation. *Ecol. Soc.* 17, 27. <https://doi.org/10.5751/ES-04520-170127>.

- Eisenbies, M.H., Vance, E.D., Aust, W.M., Seiler, J., 2009. Intensive utilization of harvest residues in southern pine plantations: quantities available and implications for nutrient budgets and sustainable site productivity. *BioEnergy Research* 2 (3), 90–98. <https://doi.org/10.1007/s12155-009-9036-z>.
- EUROSTAT, 2018. *Agriculture, Forestry and Fishery Statistics- 2018 edition*. Publications Office of the European Union.
- Farrelly, N., Ní Dhubháin, Á., Nieuwenhuis, M., Grant, J., 2009. The distribution and productivity of Sitka spruce (*Picea sitchensis*) in Ireland in relation to site, soil and climatic factors. *Irish Forestry* 66 (1), 51–73. Retrieved from. <https://journal.societyofirishforesters.ie/index.php/forestry/article/view/10023>.
- Ficko, A., Lidestav, G., Dhubhain, A.N., Karppinen, H., Zivojinovic, I., Westin, K., 2019. European private forest owner typologies: a review of methods and use. *Forest Policy Econ.* 99, 21–31. <https://doi.org/10.1016/j.forpol.2017.09.010>.
- Gildemacher, P.R., Kaguongo, W., Ortiz, O., Tesfaye, A., Woldegiorgis, G., Wagoire, W. W., Leeuwis, C., 2009. Improving potato production in Kenya, Uganda and Ethiopia: a system diagnosis. *Potato Res.* 52 (2), 173–205. <https://doi.org/10.1007/s11540-009-9127-4>.
- Hall, A., Janssen, W., Pehu, E., Rajalahti, R., 2006. *Enhancing Agricultural Innovation: How to Go beyond the Strengthening of Research Systems*. International Bank for Reconstruction and Development/The World Bank, Washington, DC. <https://doi.org/10.1596/978-0-8213-6741-4>.
- Hekkert, M.P., Suurs, R., Negro, S.O., Smits, R.E.H.M., Kuhlmann, S., 2007. Functions of innovation systems: a new approach for Analysing technological change. *Technol. Forecast. Soc. Chang.* 74 (4), 413–432. <https://doi.org/10.1016/j.techfore.2006.03.002>.
- Helmisaari, H.S., Kaarakka, L., Olsson, B.A., 2014. Increased utilization of different tree parts for energy purposes in the Nordic countries. *Scandinavian Journal of Forest Research* 29 (4), 312–322. <https://doi.org/10.1080/02827581.2014.926097>.
- Hetemäki, L., 2014. *Future of the European forest-based sector. Structural changes towards bioeconomy*. In: *What Science Can Tell Us 6*. European Forest Institute.
- Howells, J., 2006. Intermediation and the role of intermediaries in innovation. *Res. Policy* 35 (5), 715–728. <https://doi.org/10.1016/j.respol.2006.03.005>.
- Hurmekoski, E., Jonsson, R., Korhonen, J., Jänis, J., Mäkinen, M., Leskinen, P., et al., 2018. Diversification of the forest industries: role of new wood-based products. *Can. J. For. Res.* 48 (12), 1417–1432. <https://doi.org/10.1139/cjfr-2018-0116>.
- IFFPA, 2018. *An Overview of the Irish Forestry and Forest Products Sector 2017*. Irish Forest and Forestry Products Association, Dublin, Ireland.
- Jarský, V., 2015. Analysis of the sectoral innovation system for forestry of the Czech Republic. Does it even exist? *Forest Policy Econ.* 59, 56–65. <https://doi.org/10.1016/j.forpol.2015.05.012>.
- Johnson, A., 2001. *Functions in innovation system approaches*. In: *Paper Presented at the Nelson and Winter Conference, Aalborg, Denmark*.
- Kebebe, E., Duncan, A.J., Klerkx, L., De Boer, I.J.M., Oosting, S.J., 2015. Understanding socio-economic and policy constraints to dairy development in Ethiopia: a coupled functional-structural innovation systems analysis. *Agric. Syst.* 141, 69–78. <https://doi.org/10.1016/j.agsy.2015.09.007>.
- Kieft, A., Harmsen, R., Hekkert, M.P., 2017. Interactions between systemic problems in innovation systems: the case of energy-efficient houses in the Netherlands. *Environ. Innov. Soc. Trans.* 24, 32–44. <https://doi.org/10.1016/j.eist.2016.10.001>.
- Kittredge, D.B., 2005. The cooperation of private forest owners on scales larger than one individual property: international examples and potential application in the United States. *Forest Policy Econ.* 7 (4), 671–688. <https://doi.org/10.1016/j.forpol.2003.12.004>.
- Klein Woolthuis, R., Lankhuizen, M., Gilsing, V., 2005. A system failure framework for innovation policy design. *Technovation* 25 (6), 609–619. <https://doi.org/10.1016/j.technovation.2003.11.002>.
- Klerkx, L., Van Mierlo, B., Leeuwis, C., 2012. *Evolution of Systems Approaches to Agricultural Innovation: Concepts, Analysis and interventions Farming Systems Research into the 21st century: The new dynamic*. Springer, pp. 457–483.
- Knoke, D., Yang, S., 2008. *Social network analysis*. Sage.
- Kubeczko, K., Rametsteiner, E., Weiss, G., 2006. The role of sectoral and regional innovation systems in supporting innovations in forestry. *Forest Policy Econ.* 8 (7), 704–715. <https://doi.org/10.1016/j.forpol.2005.06.011>.
- Kuuluvainen, J., Karppinen, H., Hänninen, H., Uusivuori, J., 2014. Effects of gender and length of land tenure on timber supply in Finland. *J. For. Econ.* 20 (4), 363–379. <https://doi.org/10.1016/j.jfe.2014.10.002>.
- Lamprinoupolou, C., Renwick, A., Klerkx, L., Hermans, F., Roep, D., 2014. Application of an integrated systemic framework for analysing agricultural innovation systems and informing innovation policies: comparing the Dutch and Scottish agrifood sectors. *Agric. Syst.* 129, 40–54. <https://doi.org/10.1016/j.agsy.2014.05.001>.
- Lawrence, A., 2018. Do interventions to mobilize wood lead to wood mobilization? A critical review of the links between policy aims and private forest owners' behaviour. *Forestry Int. J. Forest Res.* 91 (4), 401–418. <https://doi.org/10.1093/forestry/cpy017>.
- Lawrence, A., Deuffic, P., Hujala, T., Nichiforel, L., Feliciano, D., Jodkowski, K., Lind, T., Marchal, D., Talkkari, A., Teder, M., Vilkkiste, L., 2020. Extension, advice and knowledge systems for private forestry: understanding diversity and change across Europe. *Land Use Policy* 94, 401–418. <https://doi.org/10.1016/j.landusepol.2020.104522>, 104522.
- Lazarevic, D., Kautto, P., Antikainen, R., 2019. Finland's wood-frame multi-storey construction innovation system: Analysing motors of creative destruction. *Forest Policy Econ.* <https://doi.org/10.1016/j.forpol.2019.01.006>.
- Lind-Riehl, J., Jeltama, S., Morrison, M., Shirkey, G., Mayer, A.L., Rouleau, M., Winkler, R., 2015. Family legacies and community networks shape private forest management in the western Upper Peninsula of Michigan (USA). *Land Use Policy* 45, 95–102. <https://doi.org/10.1016/j.landusepol.2015.01.005>.
- Lundvall, B.A., Johnson, B., Andersen, E.S., Dalum, B., 2002. National systems of production, innovation and competence building. *Research Policy* 31 (2), 213–231. [https://doi.org/10.1016/S0048-7333\(01\)00137-8](https://doi.org/10.1016/S0048-7333(01)00137-8).
- Ma, Z., Kittredge, D.B., Catanzaro, P., 2012. Challenging the traditional forestry extension model: insights from the woods forum program in Massachusetts. *Small-scale Forestry* 11 (1), 87–100. <https://doi.org/10.1007/s11842-011-9170-2>.
- Mackinnon, J., 2019. *Review of Approval Processes for Afforestation in Ireland*. Report commissioned by the Department of Agriculture Food and Marine (DAFM), Dublin.
- Maguire, K., Ní Dhubháin, Á., Farrelly, N., 2010. The suitability of the private forest estate in Ireland for thinning. *Irish Forestry* 67 (1&2), 21–37.
- Malerba, F., 2002. Sectoral systems of innovation and production. *Res. Policy* 31 (2), 247–264. [https://doi.org/10.1016/S0048-7333\(01\)00139-1](https://doi.org/10.1016/S0048-7333(01)00139-1).
- Malerba, F., 2004. *Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe*. Cambridge University Press.
- Malone, J., 2008. *Factors Affecting Afforestation in Ireland in Recent Years*. Report commissioned by the Department of Agriculture and Food (DAF).
- Mantau, U., Saal, U., Prins, K., Steierer, F., Lindner, M., Verkerk, H., Asikainen, A., 2010. *Real Potential for Changes in Growth and Use of EU Forests*. EUwood, Hamburg. Methodology Report.
- Marsden, T., Millbourne, P., Kitchen, L., Bishop, K., 2003. Communities in nature: the construction and understanding of forest narratives. *Sociol. Rural.* 43, 238–256. <https://doi.org/10.1111/1467-9523.00243>.
- Merriam, S.B., Tisdell, E.J., 2015. *Qualitative Research: A Guide to Design and Implementation*. John Wiley & Sons.
- Moffat, K., Lacey, J., Zhang, A., Leipold, S., 2016. The social licence to operate: a critical review. *Forestry Int. J. Forest Res.* 89 (5), 477–488. <https://doi.org/10.1093/forestry/cpv044>.
- Neeson, E., 1991. *A History of Irish Forestry*. Lilliput Press Ltd.
- Nelson, R., 1993. *National innovation systems: a comparative analysis*. Oxford University Press.
- Ní Dhubháin, Á., 2015. Sustainable, innovative mobilization of wood resources (SIMWOOD). In: *WP2 - European Summary Report of Regional Profiles of Wood Mobilisation Challenges*.
- Ní Dhubháin, Á., Fléchar, M.-C., Moloney, R., O'Connor, D., 2009. Stakeholders' perceptions of forestry in rural areas—two case studies in Ireland. *Land Use Policy* 26, 695–703. <https://doi.org/10.1016/j.landusepol.2008.09.003>.
- Ní Dhubháin, Á., Maguire, K., Farrelly, N., 2010. The harvesting behaviour of Irish private forest owners. *Forest Policy and Economics* 12 (7), 513–517. <https://doi.org/10.1016/j.forpol.2010.05.008>.
- Ní Dhubháin, Á., Upton, V., Ryan, M., Keary, K., 2015. *Forest Land Ownership Change in Ireland*. COST Action FP1201 Forest Land Ownership Change in Europe: Significance for Management and Policy (FACESMAP).
- Nybakk, E., Lawrence, A., Weiss, G., 2015. *Innovation in Forest Management for new Forest Owner Types—A Literature Review Background Paper of Working Group 2 “New Forest Management Approaches”, COST Action FP1201 “Forest Land Ownership Changes in Europe: Significance for Management and Policy”*.
- O'Hara, J., 2021. *Implementation of the Mackinnon Report Advice to the Minister of State for Land Use and Biodiversity on Improving the Delivery of Forestry Licensing Processes*. Report commissioned by the Department of Agriculture Food and Marine (DAFM), Dublin.
- Orazio, C., Kies, U., Edwards, D., Cordero Montoya, R., Lovrić, N., Hayes, S., et al., 2017. *Handbook for Wood Mobilisation in Europe. Measures for Increasing Wood Supply from Sustainably Managed Forests*. EU SIMWOOD Project. European Forest Institute.
- Phillips, H., Corrigan, E., McDonagh, M., Fairgrieve, M., Farrelly, N., Redmond, J., Barrett, F., et al., 2016. *All Ireland Roundwood Production Forecast 2016-2035*. COFOR. Department of Agriculture, Food and the Marine, Dublin.
- Pöllmäe, P., Korjus, H., Paluots, T., 2014. Management motives of Estonian private forest owners. *Forest Policy Econ.* 42, 8–14. <https://doi.org/10.1016/j.forpol.2014.02.0077>.
- Prager, K., Thomson, K., 2014. *AKIS and Advisory Services in the Republic of Ireland Report for the AKIS Inventory (WP3) of the PRO AKIS Project*. [www.proakis.eu/publicationsandevents/pubs](http://www.proakis.eu/publicationsandevents/pubs).
- Prell, C., Hubacek, K., Reed, M., 2009. Stakeholder analysis and social network analysis in natural resource management. *Soc. Nat. Resour.* 22 (6), 501–518. <https://doi.org/10.1080/08941920802199202>.
- Rametsteiner, E., Weiss, G., 2006. Innovation and innovation policy in forestry: linking innovation process with systems models. *Forest Policy Econ.* 8 (7), 691–703. <https://doi.org/10.1016/j.forpol.2005.06.009>.
- Rametsteiner, E., Weiss, G., Ollonqvist, P., Slee, B., 2010. *Policy Integration and Coordination: The Case of Innovation and the Forest Sector in Europe*. COST Office.
- Ribe, R.G., 2006. Perceptions of forestry alternatives in the US Pacific Northwest: information effects and acceptability distribution analysis. *J. Environ. Psychol.* 26, 100–115. <https://doi.org/10.1016/j.jenvp.2006.05.004>.
- Rickenbach, M., 2009. Serving members and reaching others: the performance and social networks of a landowner cooperative. *Forest Policy Econ.* 11 (8), 593–599. <https://doi.org/10.1016/j.forpol.2009.08.006>.
- Rivera, E.A., Nieuwenhuis, M., 2018. A GIS-based site suitability assessment of harvest residue procurement during integrated first thinning operations in southern and eastern Ireland. *Irish Forestry* 75.
- Schiffer, E., Hauck, J., 2010. Net-map: collecting social network data and facilitating network learning through participatory influence network mapping. *Field Methods* 22 (3), 231–249. <https://doi.org/10.1177/1525822X10374798>.
- Scott, A., 2011. Focussing in on focus groups: effective participative tools or cheap fixes for land use policy? *Land Use Policy* 28 (4), 684–694. <https://doi.org/10.1016/j.landusepol.2010.12.004>.

- Secco, L., Pisani, E., Da Re, R., Rogelja, T., Burlando, C., Vicentini, K., et al., 2019. Towards a method of evaluating social innovation in forest-dependent rural communities: first suggestions from a science-stakeholder collaboration. *Forest Policy Econ.* 104, 9–22. <https://doi.org/10.1016/j.forpol.2019.03.0111>.
- Smits, R., Kuhlmann, S., 2004. The rise of systemic instruments in innovation policy. *Int. J. Foresight Innov. Policy* 1 (1–2), 4–32. <https://doi.org/10.1504/IJFIP.2004.004621>.
- Sosa, A., Acuna, M., McDonnell, K., Devlin, G., 2015. Controlling moisture content and truck configurations to model and optimise biomass supply chain logistics in Ireland. *Appl. Energy* 137, 338–351. <https://doi.org/10.1016/j.apenergy.2014.10.018>.
- Spielman, D.J., Birner, R., 2008. How innovative is your agriculture?: Using innovation indicators and benchmarks to strengthen national agricultural innovation systems. World Bank.
- Stern, T., Weiss, G., Bostrom, C., Huber, W., Koch, S., Schwarzbauer, P., 2013. Identifying measures for wood mobilisation from fragmented forest ownerships based on case studies from eight European regions. *Jahrb Österr Ges Für Agrarökon* 22, 19–28.
- Stoettner, E.M., Ní Dhubháin, Á., 2017. The social networks of Irish private forest owners: an exploratory study. *Forest Policy Econ.* <https://doi.org/10.1016/j.forpol.2017.09.008>.
- Toppinen, A., Toivio, M., Suur-Uski, O., Lähinen, K., Mikkilä, M., 2016. Corporate responsibility reporting in promoting social license to operate in forestry and sawmilling industries. *Forestry Int. J. Forest Res.* 89 (5), 525–541. <https://doi.org/10.1093/forestry/cpv055>.
- Turner, J.A., Klerkx, L., Rijswijk, K., Williams, T., Barnard, T., 2016. Systemic problems affecting co-innovation in the New Zealand agricultural innovation system: identification of blocking mechanisms and underlying institutional logics. *NJAS - Wageningen J. Life Sci.* 76, 99–112. <https://doi.org/10.1016/j.njas.2015.12.001>.
- UNECE/FAO [United Nations Economic Commission for Europe/Food and Agriculture Organization of the United Nations], 2020. *Who Owns our Forests? Forest Ownership in the ECE Region*. United Nations Publications, Geneva.
- Upton, V., Dhubháin, Á.N., Bullock, C., 2012. Preferences and values for afforestation: the effects of location and respondent understanding on forest attributes in a labelled choice experiment. *Forest Policy Econ.* 23, 17–27. <https://doi.org/10.1016/j.forpol.2012.06.006>.
- Upton, V., O'Donoghue, C., Ryan, M., 2014. The physical, economic and policy drivers of land conversion to forestry in Ireland. *J. Environ. Manag.* 132, 79–86. <https://doi.org/10.1016/j.jenvman.2013.10.017>.
- Upton, V., Ryan, M., Heanue, K., Ní Dhubháin, Á., 2017. The role of extension and forest characteristics in understanding the management decisions of new forest owners in Ireland. *Forest Policy Econ.* <https://doi.org/10.1016/j.forpol.2017.09.016>.
- Wasserman, S., Faust, K., 1994. *Social Network Analysis: Methods and Applications* (Vol. 8). Cambridge University Press.
- Weber, K.M., Rohrer, H., 2012. Legitimizing research, technology and innovation policies for transformative change: combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. *Res. Policy* 41 (6), 1037–1047. <https://doi.org/10.1016/j.respol.2011.10.015>.
- Weiss, G., Pettenella, D., Ollonqvist, P., Slee, B., 2011. *Innovation in Forestry: Territorial and Value Chain Relationships*. CABI.
- Weiss, G., Lawrence, A., Lidestav, G., Feliciano, D., Hujala, T., 2016. *Changing Forest Ownership in Europe – Main Results and Policy Implications*. COST Action FP1201 Forest Land Ownership Change in Europe: Significance for Management and Policy (FACESMAP) 2012–2016.
- Weiss, G., Lawrence, A., Hujala, T., Lidestav, G., Nichiforel, L., Nybakk, E., et al., 2018. Forest ownership changes in Europe: State of knowledge and conceptual foundations. *Forest Policy Econ.* <https://doi.org/10.1016/j.forpol.2018.03.003>.
- Weiss, G., Lawrence, A., Hujala, T., Lidestav, G., Nichiforel, L., Nybakk, E., Živojinović, I., 2019. Forest ownership changes in Europe: state of knowledge and conceptual foundations. *Forest Policy Econ.* 99, 9–20. <https://doi.org/10.1016/j.forpol.2018.03.003>.
- Wieczorek, A.J., Hekkert, M.P., 2012. Systemic instruments for systemic innovation problems: a framework for policy makers and innovation scholars. *Sci. Public Policy* 39 (1), 74–87. <https://doi.org/10.1093/scipol/scr008>.
- Winkel, G., Derks, J., 2016. The nature of Brexit. How the UK exiting the European Union could affect European forest and (forest related) environmental policy. *Forest Policy Econ.* 70 (C), 124–127. <https://doi.org/10.1016/j.forpol.2016.06.007>.
- Živojinović, I., Weiss, G., Lidestav, G., Feliciano, D., Hujala, T., Dobšinská, Z., et al., 2015. *Forest land ownership change in Europe*. In: COST Action FP1201 FACESMAP Country Reports, Joint Volume. EFICEEC-EFISEE Research Report. University of Natural Resources and Life Sciences, Vienna (BOKU), Vienna, Austria, p. 693.