



# Understanding the barriers and enablers to agroforestry adoption in Ireland through an innovation systems approach

Rachel Irwin<sup>a,b,\*</sup> , Ian Short<sup>a</sup>, Áine Ní Dhubháin<sup>b</sup>

<sup>a</sup> Forestry Development Department, Teagasc, Ashtown Research Centre, Dublin 15, Ireland

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

## ARTICLE INFO

### Keywords:

Agroforestry  
Innovation system  
Ireland  
Combined coupled structural-functional analysis  
Uptake failures

## ABSTRACT

The innovation of agroforestry is relatively new in Ireland, with uptake lagging behind targets. This study aimed to identify the reasoning behind this and identify the main barriers to the uptake of agroforestry. The Innovation Systems Approach was used as the analytical framework to the study whereby a structural-functional analysis was used to identify the main barriers/blocking mechanisms. Thirty-three interviews across all four domains of the innovation system (research, intermediary, enterprise and influencing) were undertaken with actors from the wider agricultural and forestry sectors networks. The results demonstrate the following key failures of the current Irish Agroforestry Innovation system: a low level of knowledge of agroforestry; a lack of research undertaken and capacity; a lack of interaction between actors; policy issues; and a lack of goals within actor organisations in supporting and promoting agroforestry. The paper provides a number of recommendations aimed at reducing the identified failures laid out as a set of goals.

## 1. Introduction

Within the last few centuries, the rapidly increasing world population in conjunction with heightened consumer demand has put pressure on the agricultural sector to produce more food (FAO, 2014; Foresight, 2011). To meet this demand, more land has been needed for agriculture and deforestation has ensued. Ireland also experienced this trend and by the beginning of the 20th century, only 1 % of its land surface was covered in trees (Neeson, 1991). Government efforts to increase tree cover in the early 20th century focussed initially on increasing state afforestation followed by a focus on private afforestation and the increase of tree cover on farms. Currently, due to those efforts, forest cover accounts for 11.6 % of the Republic of Ireland's land surface with a target of 18 % by 2046 (Department of Agriculture, Food and the Marine, 2022). If the current low level of annual afforestation (circa 2000 ha) in the Republic Ireland continues, this target will not be achieved.

Increasing tree cover on farms to result in both livestock or crop production existing in harmony with trees on the same parcel of land may be the key needed to achieve this target while also reducing the detrimental impacts that some of the current agricultural land management practices have on the environment. This land management practice is referred to as agroforestry (Raskin and Osborn, 2019). Within

agroforestry systems, there is a direct interaction between the agricultural enterprise and the tree component. According to Lawson et al. (2016), there are four distinct practices of agroforestry: silvopastoral agroforestry, the integration of livestock and trees; silvoarable agroforestry, the integration of

crops and trees; agrosilvopastoral, the integration of crops, livestock and trees; and linear forms of agroforestry such as shelterbelts, riparian buffer strips and windbreaks. There are many benefits to agroforestry including increasing carbon sequestration (Nair et al., 2009), reducing thermal stress of livestock (Woodland Trust, 2013), reducing pest abundances (Pumariño et al., 2015) and increasing local biodiversity (Udawatta et al., 2019). In recognition of the potential benefit of agroforestry to both the forestry and agricultural sectors, the Irish Government introduced an agroforestry grant scheme in 2015 in the hope that providing a financial incentive to farmers may increase uptake of this practice. This financial incentive included a grant that covers the cost of establishing an agroforestry system as well as an annual premium payment for 5 years. However, almost ten years on and despite a recent increase in the value of the financial supports for agroforestry, uptake remains critically low with only 51ha out of the targeted 195 ha of agroforestry planted; a high proportion of this area of agroforestry established under this scheme was used as demonstration plots (Curran,

\* Corresponding author. Forestry Development Department, Teagasc, Ashtown Research Centre, Dublin 15, Ireland.

E-mail address: [rachel.irwin1@ucdconnect.ie](mailto:rachel.irwin1@ucdconnect.ie) (R. Irwin).

personal communication).

Previous research on the barriers to agroforestry uptake in the Republic of Ireland has focused solely on the perceptions and attitudes of the farming community towards this land management practice (Irwin et al., 2022, 2023); research on the potential barriers that prevail within the wider agricultural and forestry network is lacking. This research also demonstrated that farmers' decision-making regarding planting trees on their farms is greatly influenced by the views of family members and other actors involved within these wider networks (Irwin et al., 2023). As such, it is vital to investigate the views of these actors in order to aid in understanding a lack of agroforestry uptake in Ireland. Common barriers identified in previous studies on farmers' decision-making regarding agroforestry in Ireland (ibid) include a lack of knowledge on the concept of agroforestry and a lack of awareness of the schemes currently available. The researcher argues that the lack of tradition and overall awareness of agroforestry, in addition to the relatively new inclusion of agroforestry as a grant aided land management practice demonstrates its novelty and agroforestry can thus be referred to as an innovation (Mercer, 2004). In order to determine and increase the success of integrating this innovation within Irish agriculture, an assessment of its innovation system is required.

According to the World Bank (2006, pg 16) an innovation system is "a 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 their behaviour and performance." To determine the barriers to agroforestry adoption that prevail within the wider agricultural sector, an Innovation Systems (IS) approach is used as the analytical framework. This approach has been commonly used when analysing the communication pathways and structures required in order to facilitate the adoption of an innovation within specific sectors of an economy (Edquist, 2013) such as the transport sector in Norway and Canada (Koasidis et al., 2020); the tourism sector in Thailand (Chunhavuthiyanon and Intarakummerd, 2014); the forestry sector in Austria (Kubeczko et al., 2006), the Czech Republic (Jarský, 2015) and the Republic of Ireland (Kilcline et al., 2021), and, the agricultural sector in Nigeria (Agwu et al., 2008) and Germany (Busse et al., 2015).

According to the IS approach, innovation is a result of a series of evolutionary and interactive processes involving engagement between a wider network of actors (Smits and Kuhlmann, 2004) and is a

combination of social, organisational, technological, institutional and economic changes (Hall et al., 2006a; Klerkx et al., 2012). The structures and functions of the broader policy arena and institutions determine the speed and direction of actor engagement (Hall et al., 2006a; Hermans et al., 2013; Klerkx et al., 2010). A variety of infrastructures, namely the research, physical and communication infrastructures, and innovation system structures shape the role of, and interactions between, actors (Hall et al., 2006a; Wiczorek and Hekkert, 2012). These innovation system structures include both informal rules such as traditions, attitudes and values, and formal rules such as regulations, laws and intellectual property rights.

This research sets out to use an IS approach to determine the main views of actors involved within the agricultural and forestry sectors in Ireland and identify barriers within the current innovation system of agroforestry in Ireland that are currently in place and impeding agroforestry uptake.

### 1.1. Methods of applying the innovation systems approach to agriculture

This study applies the IS approach to agroforestry, a land management practice that combines trees and agriculture. There are currently two main methods used by researchers when applying this approach to innovations in agriculture: the Agricultural Knowledge and Information System (AKIS) concept; and, the Agricultural Innovation Systems concept (AIS). The former was created as an advancement of the "limited" linear approach of National Agricultural Innovation Systems

first developed in the 1970s (Spielman and Birner, 2008). AKIS was developed to aid researchers understand why farmers adopted specific innovations through focusing on research dissemination from primarily a formal research system perspective (Röling, 1990); this concept focused on the "knowledge triangle" which centered the farmer between extension, research and education (see Fig. 1). Within this approach, the farmer is the central receiver of information through the formal dissemination of research from only these three domains. However, the transfer of research from solely a formal based system may not meet the actual knowledge requirements of farmers and fails to provide adequate incentives for research and education collaboration (Aerni et al., 2015). The AIS concept goes beyond the traditional research and development (R & D) pathways proposed by AKIS and provides a framework to explain and analyse the complex relationships between multiple actors, policies, institutions and infrastructures that are key to facilitating a suitable environment to enable innovation (Spielman and Birner, 2008). As such, the AIS concept was deemed the most appropriate method to apply the IS approach to the innovation of agroforestry within Irish agriculture.

Innovation capacity in agriculture is a three tier process that must be promoted at an individual level, at an organizational level and at a policy level (FAO, 2014). Education and training are required in order to develop innovation at an individual level, while the development of innovation at an organizational level through producers and organisations within the farming community and beyond is required to enable innovation between farmers. Promotion of innovation at a policy level through the creation of adequate rules and policies is important to facilitate a well-functioning enabling environment (FAO, 2014).

The agricultural sector in Ireland can be described as relatively low-tech with strong traditions driving its nature. Within such sectors, innovation is not only driven by formal R & D but also by wider functional and structural elements such as market fluctuations or new methods of production (Cunningham and Ramlogan, 2016). As such, a broader innovation system approach such as the AIS approach is required which goes beyond traditional formal and informal research and development pathways and aims to identify the structure and roles of a broad range of actors. This wider innovation system approach puts greater focus on institutional influence, such as governmental bodies and public research institutes, and infrastructural influence, such as knowledge and development pathways (Aerni et al., 2015).

This research adopted a typology of actors associated with innovation systems proposed by Arnold and Bell (2001) and classified actors into four broad categories referred to as domains: the research, enterprise, influencing and intermediary domains (see Fig. 2). This typology of actors has been used previously to assess agricultural and forestry innovation systems (e.g. Spielman and Birner, 2008; Lamprinopoulou et al., 2014; Kilcline et al., 2021) and has been suggested by many researchers as a useful method to identify organisations associated with

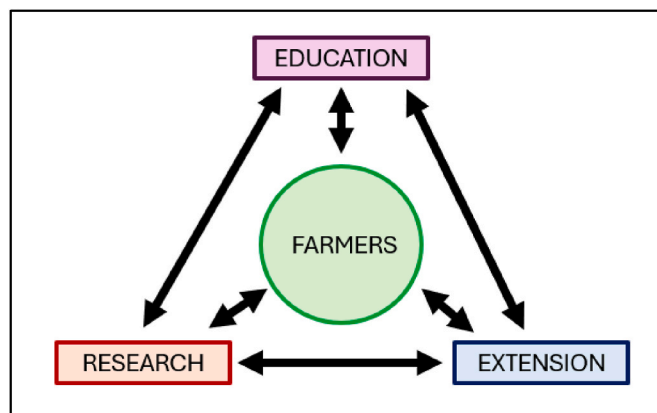


Fig. 1. The "knowledge triangle" of AKIS.

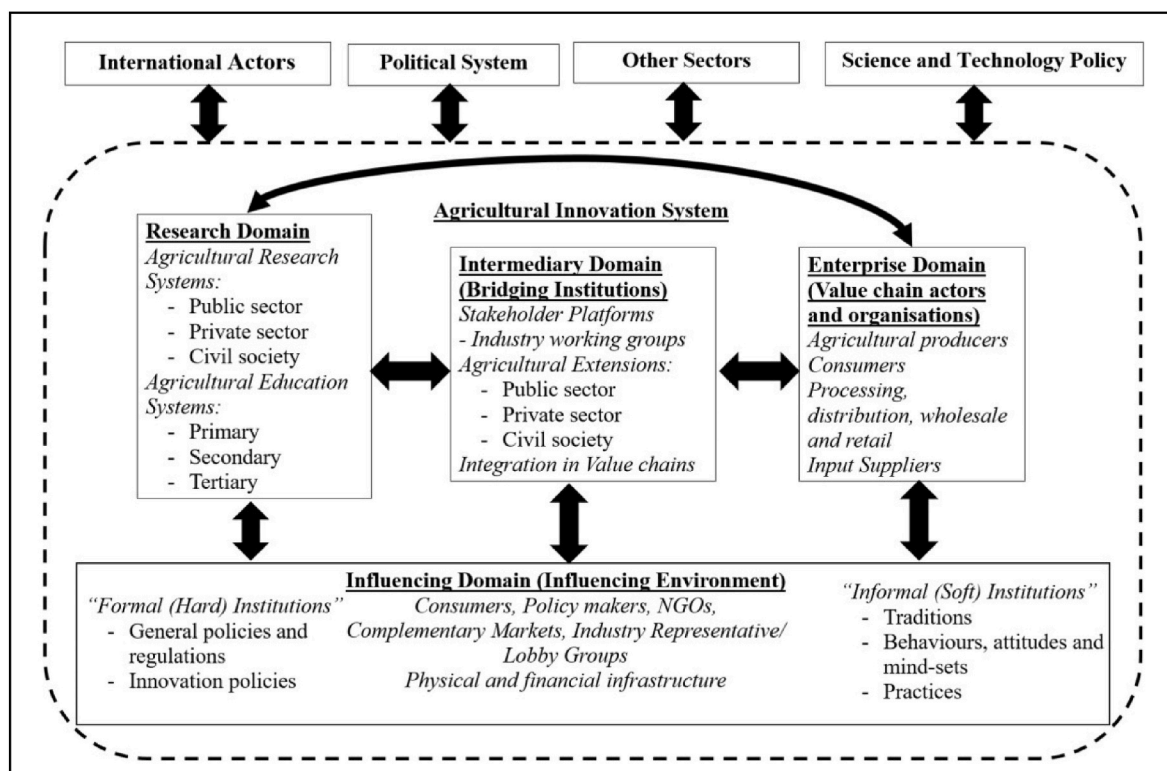


Fig. 2. Agricultural innovation systems (adapted from Anandajayasekeram, 2022).

specific sectors (e.g. Hall et al., 2006b). Although not mutually exclusive, these domains aid the researcher in identifying the types of actors that are vital to allow the sector to function appropriately and act as a starting point for investigation. In the agricultural context, the research domain comprises agricultural research systems from both the public and private sector, in addition to systems within the civil society. It also encompasses primary, secondary and tertiary agricultural education systems. The intermediary domain is also known as bridging institutions for its ability to bridge together unrelated actors to enable the flow of knowledge and innovation. In the case of agriculture this domain consists of industry working groups, private or public agricultural consultancies and advisors, farmers and farming representative bodies. The enterprise domain includes actors involved in the value chain that produce tacit knowledge rather than codified or scientific knowledge used predominantly by actors within the research domain. Actors within this domain in agriculture include input suppliers, agricultural companies and actors involved in the processing, distribution and wholesale sectors such as marts and factories as well as consumers. The final domain refers to the influencing domain and includes both formal institutions, such as policy and regulations, and informal institutions, such as traditions, attitudes and cultural attributes (Arnold and Bell, 2001). Actors within this domain highly influence the shape of the sector's innovation environment. The innovation system consisting of these four domains is also indirectly influenced by international actors, broader policies regarding science and technology, various other sectors, best practice guidelines and the broader political system. A variety of infrastructures, namely the research, physical and communication infrastructures, and innovation system structures shape the role of and interactions between these actors (Hall et al., 2006a; Wiczorek and Hekkert, 2012).

As stated above, the final domain relates to actors and institutions that directly and indirectly impact the adoptability of a specific innovation. Social networks, which enable knowledge transfer between actors and impact decision making, are a vital component within this domain. Such social networks have been identified as having a crucial

role in technology adoption at farm level (Conley and Udry, 2016; Wuepper et al., 2014). They encourage farmers to adjust their behaviour through their desire to meet the expectations of influential actors (Moser and Barrett, 2006; Spielman et al., 2008). Social networks also facilitate knowledge transfer and diffusion of new innovations particularly when deficits are evident in formal extension infrastructure and institutions, while also enabling access to the required resources to adopt such innovations (Hartwich and Scheidegger, 2010; Larsen et al., 2009). Similar to the effect of social networks on the adoption of innovative practices, previous research on farmers' decision-making regarding planting trees on their farm in Ireland has demonstrated the high influence of subjective norms (Irwin et al., 2023). These subjective norms relate to influential people within the farming community such as local farmers, their agricultural advisors and their family. These influential people make up a farmer's social network.

### 1.2. Structural-functional analysis

Functional analysis of an innovation system aims to identify the functional components that are the drivers behind performance and transitions towards such innovations. When aiming to identify the functions within an IS, Edquist and Johnson (1997) stated that IS have three main fundamental functions: providing information to reduce uncertainties; managing conflict and aiding cooperation; and, creating financial and non-financial incentives for innovation creation. This was further extended by Hekkert et al. (2007) following their historic overview of literature relating to the functions of an innovation system to seven main functions that determine the functional performance of an IS.

- [F1] Entrepreneurial activities;
- [F2] Knowledge development;
- [F3] Knowledge dissemination;
- [F4] Guidance of the search;
- [F5] Market formation;

- [F6] Resource mobilisation; and,
- [F7] Creation of legitimacy.

F1 refers to the entrepreneurs within a specific innovation system; their presence and activity acts as an indicator of the performance of the IS. To what extent this function is fulfilled can be determined by the number of new entrants into the sector and experiments in relation to new technology, in addition to the number and diversity of required actors' activities. F2 & F3 refer to knowledge development and its dissemination. Mapping the number of R & D projects, patents, investments in the knowledge infrastructure, the number of workshops and conferences which have a singular focus on the specific innovation and the size and intensity of the network over specific time periods can aid the researcher in determining how well these functions are fulfilled (Hekkert et al., 2007).

F4, guidance of the search, refers to the creation of a vision of the IS that positions and orientates the remaining functions towards meeting a shared goal for the sector. The shared goal is influenced by the long term goals of policy and specific societal preferences. This function allows heightened clarity and visibility among the users' needs and treats the innovation as a variable rather than a constant. How well the innovation system facilitates this function is determined by mapping specific goals and targets of the users of the specific innovation or technology and quantitative research on historic events, such as the inclusion within policy or the publishing of journal articles (Hekkert et al., 2007). F5 refers to market formation and creates a platform for users to learn about the specific innovation (F2-3) which aids in developing their expectation (F4). Analysing to what extent this function is facilitated can take the form of mapping niche markets or tax regimes specific to new innovations and technologies.

Resource mobilisation is encompassed in F6 and includes both financial and human resources. According to Hekkert et al. (2007), this function proves difficult to quantifiably measure. The perceptions of actors on whether or not specific resources are difficult to access may aid in determining the fulfilment of this function. The final function, F7, relates to the creation of legitimacy and to counteracting resistance to change. Mapping the number of interest groups, their growth and their lobby actions can aid in identifying if the specific IS appropriately facilitates this function.

The presence and quality of the structural elements of an innovation system, such as its actors and their interactions, infrastructures (knowledge, physical and financial), and institutions within an innovation system determines its structural performance and functioning (Klein Woolthuis et al., 2005). Despite this evident link between the structural components and functioning of an innovation system, many studies choose to isolate these components and focus on either the structural or functional aspects. To combine both the structural and functional analysis of an innovation system, Wieczorek and Hekkert (2012) proposed the "coupled structural-functional analysis" which enables the researcher to identify the presence and quality of the structural components of the IS using the typology proposed by Klein Woolthuis et al. (2005) through determining the effectiveness of the IS functioning using the typology proposed by Hekkert et al. (2007). Through using this coupled structural-functional analysis, structural failures within the IS, known as "blocking mechanisms" can be identified. These blocking mechanisms relate to underlying systemic issues that impact on the performance and the relationship between such issues that may arise due to historically developed practices, attitudes, misconceptions and widely accepted rules (Turner et al., 2016).

Nine categories of blocking mechanisms/failures have been accepted within literature. Klein Woolthuis et al. (2005) proposed four initial failures namely.

- [B1] Infrastructure failures (the absence of physical, knowledge and financial infrastructures);

- [B2] Institutional failures (such as missing or defunct formal and informal institutions; these take the form of the presence of laws or regulations known as hard institutional failures, or the presence of customs and social norms known as soft institutional failures);
- [B3] Interaction failures (such as missing or defunct interactions between actors; these take the form of both strong network failures whereby there is misguidance by or an almost singular dependence or supremacy of specific actors, and, weak network failures whereby a lack of connectivity impedes learning); and,
- [B4] Actor failures (such as failures in actors' ability to utilise available resources or obtain the required capacity to learn [actor capability failures] or absence of required actors [actor presence failures]).

van Mierlo et al. (2010) further expanded on these failures and included.

- [B5] Market structure failures (such as "knowledge market" deficiencies).

Weber and Rohrer (2012) proposed the following four additional failures.

- [B6] Directionality (such as a lack of shared vision);
- [B7] Policy coordination (such as failed coordination at a policy level);
- [B8] Demand articulation (such as deficits in identifying and learning from user requirements); and,
- [B9] Reflexivity failures (such as failures in engaging actors in a self-governance process).

As the Irish agricultural innovation system (IS) can be regarded as mature according to the characteristics proposed by Kieft et al. (2017), identification of blocking mechanisms that have developed over the lifetime of the innovation system is beneficial in order to identify methods that enable transition. The Irish agricultural sector IS can be considered mature due to the presence of many feedback loops between the elements of the systems and its historical importance to the Irish economy. It is also locked into specific sectoral structures and technologies, such as a developed management and supply system (ibid). As such, this sector faces "technological and institutional lock-in" which can impede the transition towards newer more innovative practices (Kieft et al., 2017) such as agroforestry.

## 2. Methodology

### 2.1. Methodological approach

The aim of this study was to identify the barriers to agroforestry adoption that prevail within the agricultural sector using a structural-functional analysis of the agroforestry innovation system. To address this aim in-depth interviews with system actors were conducted. Actors who participated in this study were identified following a review of grey literature, interaction with evident key actors such as those engaged in the Irish Agroforestry Forum (IAF),<sup>1</sup> governmental documents and scholarly research. This study utilised a qualitative approach whereby actors were asked a set of open-ended questions framed by the structural-functional analysis approach as described above. The use of a qualitative approach allows the researcher to probe deeper into the areas of interest, allows a more in-depth exploration of emergent themes and topics, and finally, allows the researcher to generate richer contextual data. In this study it allowed the authors to better understand

<sup>1</sup> The Irish Agroforestry Forum is a group of stakeholders that provide advice and training to farmers and landowners in Ireland on agroforestry.

the blocking mechanisms currently in place that are impeding the adoption of agroforestry in the Republic of Ireland.

The interviews consisted of four parts (A full list of questions is provided in [Appendix 1](#)).

- Firstly, actors were asked a set of background questions relating to their employment role, knowledge and personal views of agroforestry and their organisations' influential status within Irish agriculture;
- Secondly, actors were asked to identify communication and information exchange pathways using a mapping approach facilitated by Zoom's whiteboard feature. Actors were asked to create a structural network through identifying with whom they exchange knowledge of agroforestry and the frequency and method of that exchange;
- Thirdly, actors were asked a set of questions based on functional analysis; and,
- Finally, actors were asked a set of additional questions based on terminology with a final question which asked them to identify potential actors to be interviewed. Actors were also asked to provide their own definition of agroforestry to determine their understanding.

Actors were invited to participate in this study via an email outlining the purpose of the research, an introduction into the researcher and the research conducted to date, and an overview of the main questions to be asked. In total, a minimum of fifteen actors from each domain were invited to attend an interview as part of this research. A follow-up email was sent if no response was received within two weeks of initial contact. Following a no response from the second email, potential participants were contacted via a phone call, where sufficient contact details were provided, reiterating the information provided within the email. Recruitment of participants occurred between July 2022 and January 2023 with a total of 33 no. actors from all four domains agreeing to participate in the research (see [Table 1](#) below). Selection of suitable domains for which actors placed was conducted following a review of the relevant literature and guidance on the relevant domains and a review of their occupation and responsibilities within their relevant institution. In some instances, actors potentially represented a number of domains; in these instances, actors were placed into the domain that best reflected their role within the institution they represented; this was conducted after the interview which included questions regarding their role. For example, actors involved in university education were identified as potentially playing a role in the research and intermediary domains however, upon further analysis of their roles, these actors were placed within the intermediary domain; both actors played a key role in transferring knowledge and advice from the research domain to the other domains. Interviews were undertaken over Zoom and lasted between thirty-five and one hundred minutes. The recording of interviews was undertaken following actors' consent using the recording option on Zoom which records both audio and video. Zoom produced an audio transcript which was then reviewed in detail to ensure an accurate transcription of the interviews was obtained. To ensure the retention of overtone, nuance and subtlety in interviews, confirmative transcription was conducted by the interviewer over the following days post interview. Any personal information relating to names mentioned within the interviews were replaced with [name removed] and pseudonyms replaced actors' names.

Interviews were conducted between September 2022 and January 2023, with recruitment of participants and subsequent interviewing continuing until saturation of themes occurred. Thematic analysis of the transcripts to identify saturation in the emergence of themes relating to the combined structural-functional analysis was undertaken by the researcher using Nvivo ([Richards, 1999](#)). This type of analysis is a method used to identify and organise patterns of meaning systematically across the data set ([Braun and Clarke, 2012](#)). Exact phrases or words were first used to construct the themes and placed into nodes to

**Table 1**  
Actors interviewed.

Stakeholder Domain	Principal Role (Actor Domain Code)	Background (Number indicates number interviewed in each area)
Research	Research and Academia (RAA)	Private Researcher (1) Lecturer in Farm management/Assistant College Farm Manager (1) Post-doctoral researcher on Agri-environmental schemes (1) Education Officer (1) [Teagasc]
Enterprise	Forest Management Companies (FMC) Private Sector Agricultural Consultant (PAC) Nursery (NY)	Forest Management Companies (1) Private Sector Agricultural Consultant (2) Native Irish Tree Nursery (1) Tree Nursery (1)
Influencing	Department of Agriculture Food and the Marine Forest Service (DAFM FS) Farmer-led Organisations (FLO)	Forestry Inspector (1) Macra (1) IFA (1) Leitrim Organic Farmers Co-op (1) Farming Article Author (1) Mart Owner (1) Project Manager (1)
Intermediary	Media (MA) Mart (MT) EIP in farmland biodiversity (EIP) Agroforester (AR) Farmer (FR)	Organic Agroforester (1) Organic Farmer (1) Conventional Farmer (1) Consumer (1) Farm Vet (1)
	Consumer (CR) Vet (VT)	Consumer (1) Farm Vet (1)
	University Education (RAA)	Lecturer/Assistant Professor in Forestry (1) Professor in Agriculture and Food Economics (1) Vocational Forestry/Arboriculture Educational Specialist (1) Forestry Specialist (1) Forestry Development Officer (1) Countryside Management Specialist (1) Business & Technology Advisor/Signpost Climate Advisor (1)
	Vocational Education (VES)	Forestry Specialist (1) Forestry Development Officer (1) Countryside Management Specialist (1) Business & Technology Advisor/Signpost Climate Advisor (1)
	Teagasc Advisory/Extension/Communications (SFA)	Forestry Specialist (1) Forestry Development Officer (1) Countryside Management Specialist (1) Business & Technology Advisor/Signpost Climate Advisor (1)
	Forum for Agroforestry Promotion (AP)	Project Coordinator Agroforestry Education and Promotion (1) Forester (1) [Coillte]
	Public Sector Forestry Consultant (PFC) Private Sector Ecological Consultant (PEC) NGOs (NGO)	Senior Ecologist (1) Pocket Forests (1) Trees on the Land (1)

represent specific themes. Once this had been conducted, the data was then re-grouped into broader themes to reflect the context of the information. Once all themes were collated, they were reviewed and transposed into the relevant blocking mechanism for which they referred to as outlined in [Section 2.2](#) above. Saturation was reached when no further themes emerged from interviews. The following section provides an outline of the results, using quotes for illustration purposes.

## 2.2. Limitations

As with any research, this research is not without its limitations. Firstly, as can be observed in [Table 1](#) above, although every effort was made to ensure a balanced representative number of actors across all domains were interviewed as part of this research, an evident imbalance

occurred. This was due to a reluctance to participate by a large number of actors contacted, mainly due to their lack of understanding of the concept of agroforestry and thus, unwillingness to comment; the term agroforestry was utilised within the invitation to participate. As such, the research poses some limitations on the potential for bias amongst the participants whereby participants were more willing to engage in the research if they were already aware, to varying knowledge levels, of the land management practice of agroforestry or were more willing to engage in research. As such, although every effort was made by the researcher utilising their available resources and capabilities, all potential communication pathways or actor links, in addition to acting barriers and enablers, may not have been captured. Additionally, a randomised sample of actors involved in the agricultural and forestry domains in Ireland may be more advantageous to identify and may build on the barriers to agroforestry adoption in Ireland; the researcher did not have access to the relevant resources in order to accommodate this and had to rely on alternate corridors of participant selection as outlined above.

Additionally, due to delays in publishing this research, it may be argued that changes may have occurred within the current innovation system of agroforestry of Ireland. However, current uptake of agroforestry in Ireland under the current Forest Type (FT) 8 scheme is still lacking behind predicted (Curran, personal communication); this demonstrates that the barriers identified within this research are still actively in place and impeding uptake. Intervention, such as through putting in place measures to reach each of the nine goals identified, is required in order to encourage Irish farmers to adopt agroforestry.

### 3. Results

In this section the blocking mechanisms/failures that were identified during the interviews have been framed according to the categories outlined above.

#### 3.1. [B1] Infrastructure failures and enablers

##### 3.1.1. Knowledge infrastructure

The results demonstrate an insufficient knowledge infrastructure [B1 Infrastructure failures] which is currently impeding the advancement of agroforestry in the Republic of Ireland. This is evident due to the low level of knowledge and experience of agroforestry amongst the majority of the actors [B4 Actor failures (actor capability failures)] combined with weak or insufficient connections between principal knowledge providers [B3 Interaction failures (weak network failures)] and lack of communication pathways between actors. Furthermore, the lack of studies incorporating social science and rural sociology of both farmers and consumers was also identified [B8 Demand articulation] further exacerbating the insufficiency of the current knowledge infrastructure.

“Those things [are] very important, that social researchers are involved. You know that kind of social science arm is brought in as well to understand people’s perception. People’s ... outlook on the change in their landscape, because agroforestry might lead to a number of changes in ... landscape views, and the way ecosystems function so whether people know those terms or not, they might be interested in just seeing how their local landscape has changed and I’d be interested in understanding their perceptions

of that.” (Research and Academia - Post-doctoral researcher on Agri-environmental schemes)

Difficulties in conducting agroforestry research were also identified by the actors. The long-term nature of agroforestry research, in relation to the short-term nature of research funding, may deter colleges and research centres from conducting such research due to the long-term commitment required by staff and land. Despite the identified absence of formal agroforestry knowledge, the majority of farmers in Ireland

may have informal experience of agroforestry due to trees being planted on farms by previous generations or left on areas of the farm that have been deemed to be of lower agricultural quality.

“No, well, not in any formal sense, though there are, yeah, I know a few people that kind of plant trees or kind of manage hedgerows well, but not in terms of kind of the you know the more structured

thing of planting lines of trees and doing it in.” (Private Sector Ecological Consultant)

According to one actor, there may even be more farmers engaging in agroforestry outside of the agroforestry grant scheme than in it.

“There’s a lot more that have agroforestry around the farms that are not aware that it’s agroforestry. Um, you know that of hedgerows and various forms of agroforestry. They have no like

concept that the two things are even related. There [may] also be a lot of ... people farming outside of the schemes that we’re not aware of.” (Forum for Agroforestry Promotion – Project Coordinator)

Furthermore, due to the current absence of field-based agroforestry research in Ireland and the removal of previous research sites, a lack of middle-aged experimental sites was identified as an issue. There is only one mature agroforestry research site in Ireland, information available on sites in their functioning stage is limited to the specific topography, climate and management of this one site. The insufficient knowledge infrastructure causes significant dysfunction amongst various functions of the innovation network most notably impacting [F1] Entrepreneurial Activity through a lack of new and existing agroforesters and [F3] Knowledge Dissemination through limited dissemination of the collated knowledge.

#### 3.1.2. Financial infrastructure

The majority of actors stated that the grant aid structure in the Republic of Ireland for agroforestry was insufficient [B1 Infrastructure failure (insufficient financial infrastructure)]. With a shorter premium payment period it was identified by the actors to be lagging behind other forestry schemes (forestry schemes generally attract a 20 years of premium payments for farmers).

Lack of promotion of the agroforestry scheme from the Forest Service and DAFM was also identified as an issue.

“Because I wonder is ... the forest service or is it the department of agriculture ... are they serious about trying to promote agroforestry or is it just you know another line in the spread sheet” (Forest Management Company Employee)

Furthermore, alterations to the subsidy scheme were deemed necessary by actors notably the changing of the scheme from a forestry scheme to an agricultural scheme and a change in payment structure from a per hectare payment to a pro rata payment whereby the rate of payment would be based on the number of trees planted per hectare. Actors stated that they believed farmers would be more willing to accept a pro rata reduction in their establishment grant if they planted a reduced number of trees per hectare. Lack of payments for ecosystem services associated with agroforestry was also identified [B1 Infrastructure failures (financial infrastructure absence)]. Furthermore, the lack of available financial data on the implications of incorporating agroforestry into a farming enterprise such as cost benefit analysis data and accurate balance sheets was identified as a barrier to uptake. It was stated that landowners do not have enough information to make an educated and informed decision on whether this would be a viable land use on their farm. As such, “the business man isn’t going to choose this option at the end of the day” (Research and Academia – Private Researcher).

“What’s maybe challenging as well [is] .... we can do a financial analysis for a mainly conifer forest or ... a reasonably fast growing broadleaf forest. But the economics of Agroforestry, if you’re just

looking at the trees alone are more challenging to even measure. I don't think they have been measured in our system.” (Teagasc Advisory – Forestry Specialist)

### 3.1.3. Physical infrastructure

The identification of physical infrastructure failures was limited due to a lack of understanding of the requirements of an agroforestry system [B8 Demand articulation]. A potential absence failure was identified at nursery level whereby supply of suitable trees may be limited if demand for agroforestry suddenly increased at farm level.

“I do think we've got a problem with supply of trees. That's like that's the sort of next elephant in the room is that ... within Ireland there are a few big specialist nurseries.” (NGO – Trees on the Land)

Furthermore, actors identified contractors as having little to no interest in carrying out tree planting at a small scale which may increase workloads for the farmer.

## 3.2. [B2] Institutional failures and enablers

In the Republic of Ireland, the main grant for agroforestry is included in a suite of forestry grants meaning it is subject to the laws and regulations binding forestry operations i.e. Forestry Act 2014. As such, once agroforestry is established under this scheme, the land becomes re-designated as forest and thus undergoes the strict regulatory provisions of forestry operations in the Republic of Ireland [B2 Institutional failures (hard institutional failures)]. Under such regulations, the felling of trees must be conducted under licence and upon their removal, operations must be put in place to ensure a sufficient number of trees are replanted. The long-term nature of agroforestry, strengthened by this permanent re-designation of the land upon engagement in the scheme [B2 Institutional failures (strong network failures)] is also a barrier to a landowner's ability to experiment with tree planting.

“The land is in the eyes of the forest service it can no longer, it has always to be agroforestry going forward. It's not a choice for someone to come back in here in five or ten or twenty years time [and say] I'd like to turn this field back into a meadow for traditional agri purposes, you know, and so that, I think is a barrier” (Forest Management Company Employee)

The re-designation of land also leads to an understanding amongst the farming community and land appraisers that such land is now deemed to be of lower value [B2 Institutional failures (weak institutional failures)].

“My personal view is that it actually devalues land. So it depends on the land. If you're talking about land that is extremely marginal and it doesn't that's fine. But if land is valuable from an

agricultural perspective by putting it under forestry you're devaluing the land because you're permanently

... prescribing that land as forestry so maybe that's devaluing the land.” (Research and Academia – Private Researcher)

Due to a current high demand for, and market value of, agricultural land in the Republic of Ireland in combination with a failure to identify the benefits of agroforestry outside the monetary benefits provided by the subsidy scheme, alternative methods of land management are often chosen as a means of risk minimisation. Leasing of land was identified as a major competitor to agroforestry in Ireland. Choosing

this option allows landowners to receive a continuous income without the risk of land devaluation; the monetary benefit provided by the main agroforestry grant in the Republic of Ireland was identified as not sufficient to counteract this perceived risk [B1 Infrastructure failures (financial)].

“If you compare it to what's available in Northern Ireland. It's great. It would be very good grant aid in comparison. So if you compare the two systems what they have, there is not sufficient for people to put agroforestry on the land. The grant here is sufficient. Um, but the that the problem is the length of the premium, because it affects the valuation of the land um, or the perceived valuation of the

land” (Forum for Agroforestry Promotion – Project Coordinator)

This re-designation of land further leads to a significant barrier to the introduction of new entrepreneurs in agroforestry [F1 Entrepreneurial activities (new entrants)]. This is further exacerbated by a lack of communication between the researchers identifying the benefits to increasing tree cover on farms, and the land owners and the appraisers. Additionally, one actor stated that a barrier to new entrepreneurs could also be attributed to the perception that the government has created a generation of farmers that only farm as prescribed by the main available funding aids provided. However, this has not been the case for a number of agri-ecological and afforestation schemes, such as agroforestry. Perhaps the reasoning behind this lies in the fact that the agroforestry scheme available in Ireland lies under the suite of forestry schemes rather than under an agricultural scheme.

“The Department have created a culture of farmers who don't think. They farm within the boundaries of whatever Grant is going on. And they farm those grants. So I think. Yeah, that's probably the

biggest cultural damage that grants have done, people don't think.” (Agroforester)

A major institutional failure identified was the lack of forestry tradition in Ireland [B2 Institutional failures (soft institutional failures)].

“ [What] will remain the biggest hurdle of all, I think, is the tradition and the stigma against trees, and it's worldwide as far as I can understand um, and it's not only Sitka spruce and the hatred of the Irish forestry system ... It may even be stronger in Ireland because of kind of social political reasons and farms being small, and colonization, and trying to fight for land and fight for survival. And it could be even

ingrained farming ideas ... even if you go back to the Ceide Fields as an example like that was over four thousand years ago. Farmers went to the effort with probably stone axes or I don't know how they did it, but they cleared the whole woodland of Scots pine to create great agricultural land ... engrained kind of civilization, or whether it's part of the Anthropocene, or whatever cleared land is good land, because its agriculture I suppose and the tradition of having trees within agricultural land is has been frowned upon, I suppose. Because yeah, cleared land is good land” (Agroforester)

This failure arises from the lack of communication and interactions between “farmers” and “foresters” [B3 Interaction failures (weak network failures)]. Amongst the farming community a common perception identified during the interviews was that a farmer who plants trees on his land is no longer a

farmer but is instead a forester. This is particularly evident with the older generation where the inclusion of planted trees on the farm is not seen as the norm. Furthermore, the lack of knowledge of the long-term benefits of agroforestry has created a subset of farmers who rely on measurable tangible and physical immediate benefits. Additionally, the concept of agroforestry can prove difficult to grasp amongst the farming community due to a historic segregation between farming and forestry. The term itself was identified as a barrier to uptake due to a lack of knowledge and evident misconceptions.

“I don't know because of the headline agroforestry its not the word It's not the word to go down. It's not that word, you want to be using a different word than agroforestry like for the ordinary

people that's knows nothing about farming think its just trees you're talking about, just you know ... Lack of knowledge when people hear agroforestry they think its another forestry like its just forestry like" (Conventional Farmer)

However, specific actors contradict this thinking. It was identified that rather than altering terminology, focus should be on altering the misconception whereas other actors acknowledged farming itself to have received a bad reputation and to be clouded by misconception. According to one actor, if farmers are truly open to the idea of increasing tree cover on their farm, the terminology will not act as a barrier to their engaging in increasing tree cover, but it would rather transform into what they believe is the best way of describing their enterprise.

### 3.3. [B3] interaction failures and enablers

#### 3.3.1. Strong interaction failures and enablers

As indicated during the interviews, there is an almost singular dependence on, or supremacy of, the Irish Agroforestry Forum (IAF) for knowledge dissemination on agroforestry amongst the actors who had expressed an existing understanding of the concept [B3 Interaction failures (strong network failures – over dependence)] (see Fig. 4). The overdependence on the IAF was counteracted by the low and insufficient levels of capacity of the forum identified by the actors to increase agroforestry uptake [B4 Actor failures (actor capability failures)].

The actors identified an overdependence on Teagasc<sup>2</sup> and other farm advisors to supply landowners with knowledge on agriculture. The Intermediary Domain actor group that Teagasc belongs to however was noted to have insufficient knowledge of agroforestry [B4 Actor failures (actor capability failures)] leading to misguidance [B3 Interaction failures (strong network failures – misguidance)].

"We need to educate the educators. I don't think there's enough information, or by and either within agricultural departments, north or south and I think they need to be educated first" (Private Sector Agricultural Consultant)

Teagasc was also identified as the main leading research body and also one of the leading funders of the research which was identified as potentially allowing for misguidance in the research [B3 Interaction failures (strong network failures)] with more cooperative research identified as a major requirement.

"Teagasc is not really independent ... I just feel Teagasc is not a very holistic organization and not independent enough kind of to look at a bigger picture and that's ok but stakeholders and the whole finance but it surely it would be good to incorporate them as well like I mean not to leave them out ... But you also need people who would have really practical experience and you don't always get that with Teagasc." (Farm vet)

#### 3.3.2. Weak network failures and enablers

A lack of engagement and knowledge transfer between agricultural advisors and other actors in the innovation network was identified [B3 Interaction failures (weak network failures)]. The overdependence on Teagasc and the Department of Agriculture, Food and the Marine (DAFM) to conduct research creates a further interaction failure whereby a lack of connectivity or actor inclusion creates a one-sided approach. Teagasc was identified as failing to have the necessary level of capacity to sufficiently undertake such research. The private agricultural researcher stated that such research involving the inclusion of trees on farms was not on their own radar. Furthermore, more

cooperative research to include nutritionists, medical people, research players, processors, farmer led organisations and environmentalists, was identified as a necessary requirement in order to obtain a broader spectrum of research.

Fig. 3 below demonstrates the communication networks between actors associated with the innovation network of agroforestry; this demonstrates the communication networks identified by the actors themselves rather than the organization or institution they represent. As shown in this figure, there were five actors that did not identify any communication pathway with any other actor. These actors were: the consumer; actor involved within a private research firm; actor involved within a private forestry company; EIP stakeholder; and mart owner. As stated above, the IAF has the largest number of communication pathways and is the main organisation in Ireland responsible for knowledge dissemination on agroforestry. Communication between actor groups was identified to occur in both a formal and informal way through various communication pathways such as Whatsapp groups, phone calls, emails, meetings, lectures and conferences. However, significant gaps in the communication network linkages between the IAF and specific actors have been identified. No direct nor indirect communication link between the IAF and consumers, private research firms, private forestry management companies, EIP Stakeholders, nor mart owners was identified. Furthermore, no direct link between the Teagasc Education Officer, Coillte, Conventional Farmer, private agricultural consultant, ecological consultant, farming independent writer, University agricultural professor, post-doctoral researcher, Teagasc agricultural advisor, Teagasc countryside specialist, Vet and nurseries were identified. There was also no direct communication pathway between agroforesters and any other actors interviewed with the exception of the IAF. A weak interaction between various researchers and both forestry and agricultural advisors was noted impeding knowledge transfer and learning from research [B3 Interaction failures (weak network failures)] creating actor failures [B4 Actor failures (actor capability failures)].

The actors identified the requirement for education and constant feeding of knowledge to farmers and landowners. According to Fig. 3, this is evidently lacking; a lack of communication pathways between the research domain, including students, and the influencing domain due to the lack of sufficient knowledge infrastructure [B1 Infrastructure failures (knowledge)] is creating interaction failures [B3] of both strong and weak network failures. As shown in Fig. 4 which represents a summary of Fig. 3 through calculating the number of interactions between actors within and between these domains, this is further exacerbated by the lack of communication pathways between the research domain and the intermediary domain reducing the transfer of knowledge gained from research to the farmers. The strength of the communication pathways is based on the frequency and occurrence of knowledge transfer between actors of the varying domains and the arrows represent the direction of the knowledge transfer; it does not account for the quality of the communication which was outside the scope of this research. Additionally, a weak interaction network amongst the research domain was identified. There was also an evident lack of knowledge flow from the Influencing domain to the enterprise domain however, a communication pathway transferring knowledge was identified from the enterprise to the influencing domain. The strongest communication pathways reflecting a transfer of knowledge was evident between the influencing and the intermediary domain with the strongest direction evident from the intermediary to the influencing domain.

### 3.4. [B4] Actor failures and enablers

As stated above, the overdependence on Teagasc advisors to provide farmers with information on new schemes and innovations is especially evident in the geographical spread of agroforesters; actors noted a high correlation between the uptake of agroforestry in a specific region and the level of interest in agroforestry exhibited by the advisors in that region. This correlation demonstrates a lack of knowledge of

<sup>2</sup> Teagasc is the agricultural and food development authority in Ireland is the national body providing integrated research, advisory and training services to the agriculture and food industry and rural communities.

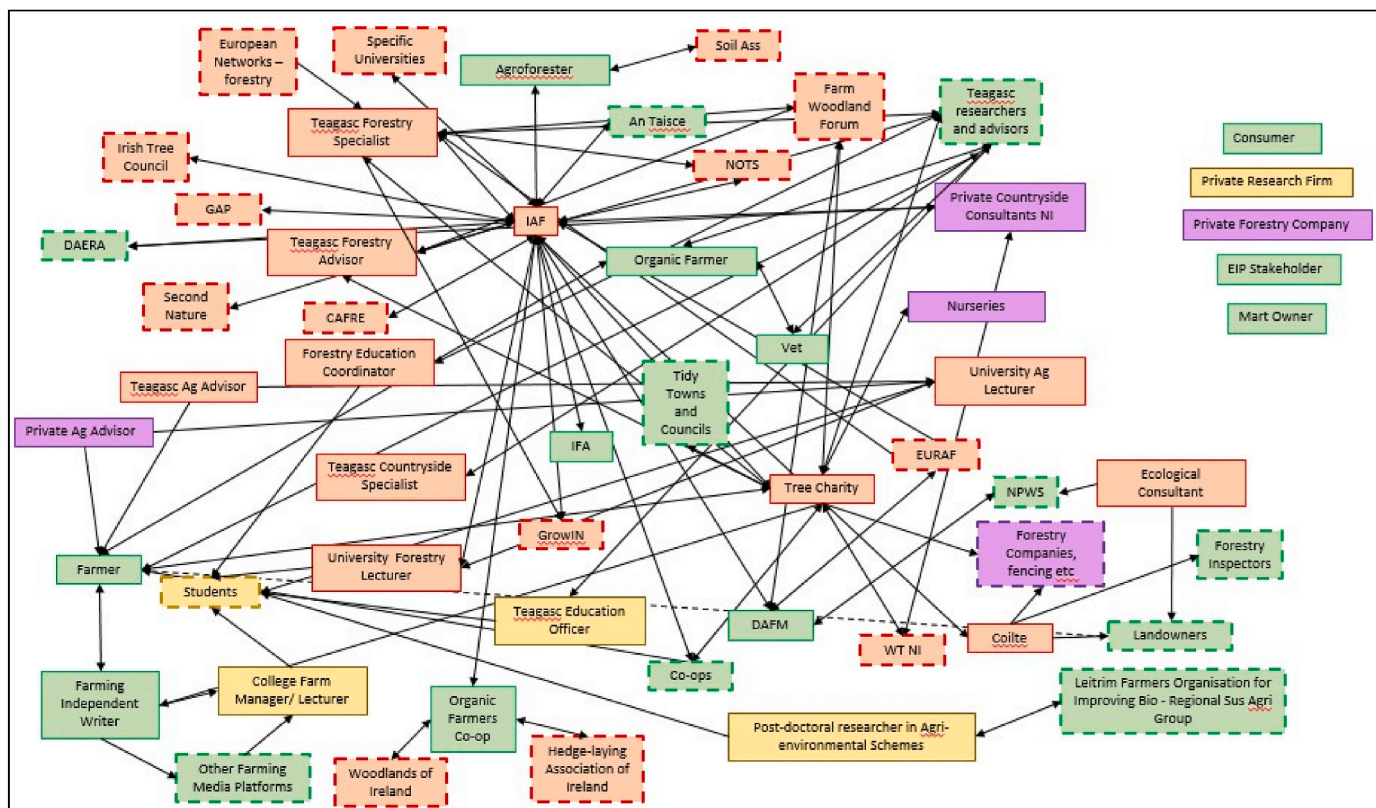


Fig. 3. Structural network between actors (green represents actors within the Influencing domain, yellow represents actors within the Research domain, purple represents actors within the Enterprise domain, and red represents actors within the Intermediary domain; a dashed box represents actors that were identified during the interviews but were not themselves interviewed; arrows represent the direction of communications; dashed lines represent that these actors are considered the same). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

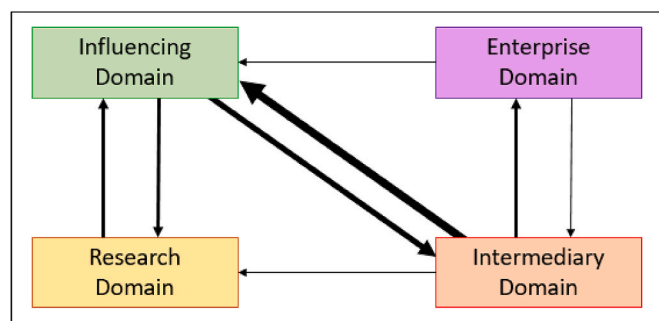


Fig. 4. Structural Network between domains (thickness of the arrows represents the strength of the communication pathway with arrows representing the direction of the pathway).

agroforestry across the entirety of the Teagasc platform; if sufficient knowledge of agroforestry was obtained by all advisors, uptake of agroforestry would not be confined to these specific geographical regions [B4.

Actor failures (actor capability failures)]. This failure is not limited to within Teagasc but is also evident within all domains; as stated above, the majority of actors could not provide a definition adequately describing agroforestry with some actors stating they were unaware of this land management practice. Furthermore, a lack of agroforesters was identified throughout the interviews, creating a low level of suitable pioneer or signpost farmers upon which farmers could interact with [B4 Actor failures (actor presence failures)].

“What you actually need is a network of demonstration farms a bit like the signpost around the country, I think, just to, so that they can visit, maybe in Agroforestry in their own area and see how it’s working, and speak to an owner who hopefully will be happy with the Agroforestry system.” (Teagasc Advisory - Forestry Specialist)

The combination of these failures in conjunction with the previously identified [B1 Infrastructure Failures] creates a positive feedback loop that can only be broken through increasing conditions which allow actor interaction to enable increased knowledge sharing.

### 3.5. [B5] Market structure failures and enablers

Throughout the interviews, the actors identified various products that could be available from farms engaging in agroforestry; physical products included firewood, ash for hurleys, woodland meat and dairy products, and fruit and nuts, while non-physical products included carbon sequestration, tourism, and trees being a capital asset. However, actors also identified specific market structure failures [B5 Market structure failures]. A lack of an established market for agroforestry products in combination with the availability of cheaper options through large supermarket chains was identified by actors as being major barriers to the uptake of agroforestry in Ireland.

Furthermore, a lack of a market for hardwood products also decreases the potential of agroforestry to be a viable enterprise option for many farmers. The current financial state of the economy, the increased cost of living and lack of disposable income were also identified as major barriers to consumers to choose more expensive products such as those that come from farms engaging in organic or agroforestry practices.

“Yes there is a certain proportion but then it goes back to what they are able to afford.

People have to cut according to their needs they're not going to yes there are people with very good income and they're very health conscious yes they will buy it. But that's a very small minority like it's a

niche market.” (Research and Academia – Lecturer in Farm Management)

One actor identified that agroforestry products should be affordable to all economic classes whereas another identified the lack of a definite label as an issue to the creation of a viable market. Other actors identified current green washing in specific established markets and a lack of mindfulness for the

environment as further market structure issues. Actors also stated the fact that products from agroforestry farms could just be a new novel attraction that may last on shelves for a limited time period before being replaced by something new. Furthermore, according to the consumer the benefits of buying such products is not clear and not available in mainstream media however people would buy in to the story if it was available.

“I don't think it's clear enough that to the public that that would be a big enough benefit for the environment over and above what they think should happen anyway on a farming system. And so why would they pay a premium for this, because it should make sense to them that the farmer does the best for

the environment, because isn't that what they are getting paid for anyway by Europe.” (Research and Academia – Post doctoral researcher on Agri-environmental schemes)

### 3.6. [B6] Directionality failures and enablers

There was a noticeable lack of goals for agroforestry amongst the actor groups interviewed with the exception of the IAF, IFA, UCD (research) and the tree charity. Although a representative from the IFA stated their goal for agroforestry, this was not agreed by other actors, with some stating the IFA to be against agroforestry.

“I think it's people are the big pushback that I get whenever I raise it with would say somebody from the IFA is that that's just a niche thing that's never going to work at scale. So yes, I think the IFA is working against it by um, patting it on the head and saying that's lovely but it's not realistic because for them the system has been based so much on, you know, ten billion litres of milk and X billion carcasses or X million carcasses of beef. Uh, you know, It's always been volume and numbers rather than

quality, and because that's where the market is.” (NGO – Pocket Forests)

The tree nursery actor stated an intention to include agroforestry in their goal for the business once information on agroforestry was provided. Teagasc forestry was identified as having a goal however this goal was not shared amongst the wider Teagasc community [B6 Directionality failures].

### 3.7. [B7] Policy, [B8] demand articulation and [B9] reflexivity failures and enablers

Although DAFM was identified as having a goal for agroforestry through their inclusion of agroforestry in the suite of forestry schemes available to landowners, promotion was severely lacking [B7 Policy coordination failures]. Furthermore, this failure was also observed in the presence of other schemes and enterprises currently being promoted by the government which were identified as being in direct competition

with agroforestry. Organic farming was stated to be the biggest competitor to agroforestry while others stated the main competitors to be conventional practices and a lack of information.

Actors also identified a lack of response from the Forest Service in Ireland to the concerns of landowners regarding the initial agroforestry scheme (GPC 11) and upon the creation of the new scheme (FT8) [B8 Demand articulation failures]. The lack of advertisement and promotion of the scheme was also identified through a lack of awareness amongst the actors that such a scheme was available. These actors

also held the perception that farmers may also be unaware of such scheme. Previously, issues with the scheme had been identified such as the short duration of the premium payment, the limiting structure of the grant in regards to where farmers could choose to plant the trees, the re-designation of land, complexity issues and the overarching barrier of the scheme being a forestry scheme rather than an agricultural scheme [B7 Policy coordination].

“I think it needs to be championed. I think that mixture between forest and agriculture needs to be worked out ... I definitely think that agroforestry ... needs to be agriculture think it's the only way it's going to get reasonable uptake as soon as you quantify it, or whatever classify land as forestry the land

value drops ... And I think with the way recruitment into agriculture is you know, farmers maybe always have [the] potential [to] sell on the farm. If it's classified as forestry and you're losing ... a potential nest egg for the future” (Private Sector Agricultural Consultant)

Furthermore, a lack of understanding of the farmers' needs and attitudes towards the scheme was evident in the fact that DAFM believe the scheme to be successful, stating that this scheme is on the increase while the uptake of similar schemes are facing a decline.

“Agroforestry is probably bucking the trend, if you like, where it's all the others who are going this way agroforestry was going this way. Now it'd be interesting to do a bit of number crunching, and just to show how it was bucking the trend, and it was actually on the increase, whereas all the others were decreasing, which showed that statistically, it probably was a success. Um, from the take up point of view, I think the going forward. Yeah, definitely, definitely. I think agroforestry is here to stay, and there

[are] all sorts of announcements all the time about it.” (DAFM – Forestry Inspector)

Furthermore, with the exception of the IAF, no actor would take responsibility for increasing agroforestry in Ireland with foresters expressing concern that it should be up to the farming organisations while the farming organisations contradicted this stating it was an issue with the forestry sector in Ireland.

Actors were asked to identify what organisations they believed to be in favour of agroforestry; Leitrim Organic farmers Co-op, the Forest Service, however only to a degree, the forestry committee of the IFA and IAF were identified. Actors acknowledge that many organisations would be against traditional coniferous forestry however they do not believe the same organisations would be against agroforestry specifically.

## 4. Discussion and recommendations

Actors across each of the four domains of research, enterprise, intermediary and influencing, were interviewed in order to identify the main structural and functional failures that are currently impeding the agroforestry innovation system. According to [Wieczorek and Hekkert \(2012\)](#), defining such systemic failures is a key element that enables the researcher to assemble strategic approaches and goals that can be put in place to create a successful and functioning innovation system. A number of failures and barriers, including subsequent goals aimed at reducing or removing these failures were identified.

Firstly, the current level of knowledge on agroforestry amongst the

actors interviewed was low with a lack of a goal for agroforestry amongst their organisations evident. This may be due to a lack of actor interactions and communication of agroforestry both within and between domains. This failure is commonly recorded when assessing innovation systems using a couple structural-functional analysis in agriculture reflecting issues with knowledge transfer and diffusion (Hailu et al., 2022; Kebebe et al., 2015; Lamprinopoulou et al., 2014; Minh and Economics, 2016; Turner et al., 2016). If the current lack of interaction and communication pathways between actors endures, connectivity between various stakeholder domains will remain pending thus impeding innovation. Therefore, it is vital that these communication pathways be created to aid in the successful adoption of agroforestry in Ireland. As such, the researcher proposes the following goal.

- [G1] Stimulate and heighten the occurrence of communication and participation amongst actors from each domain, particularly pathways that lead to the lower levels of the innovation network such as farmers and land owners.

Additionally, increasing the number of communication pathways that lead to farmers and landowners will enable a greater diversity of knowledge exchange and reduce the evident over dependence on agricultural advisors from farmers. These agricultural advisors have been identified as having a key role in knowledge exchange to farmers (Irwin et al., 2022, 2023) however they do not have the knowledge on agroforestry, nor do they have the capacity to diversify their tailored advisory remit. As identified in Section 4 above, overdependence on this actor type may lead to misguidance. The creation of new agroforestry specific advisory positions may aid in increasing agroforestry uptake and reducing the overdependence on these agricultural advisors to transfer knowledge to farmers. As such, the researcher proposes the following goal.

- [G2] Reduce the overdependence on agricultural advisors to transfer knowledge regarding agricultural practices and enable knowledge transfer from a wide variety of domains.

Knowledge and information about agroforestry has been released and has evolved in an ad hoc manner creating a knowledge system that is highly fragmented and disjointed, revolving around the main agroforestry promotion body in Ireland, the Irish Agroforestry Forum (IAF). This actor however was identified as not having the capacity to increase agroforestry adoption; this B4 Actor failure (actor capability failure) was also identified in a study regarding the barriers to enhancing research and development of agriculture in Ethiopia (Hailu et al., 2022). Although this actor actively promotes agroforestry, the lack of awareness of agroforestry during the participant recruitment stage of this research and limited knowledge on the concept from the majority of actors involved in this study demonstrates that the following goal is required.

- [G3] Increase awareness and promotion of agroforestry at various levels of the innovation network.

Policy issues such as the re-designation requirement when farmers establish agroforestry under the current scheme and the inadequate structure of this scheme were identified as barriers to uptake. This

finding reflects the results of a study conducted on the Irish forest sector innovation system regarding wood mobilisations (Kilcline et al., 2021). Perhaps this reflects a narrow view from policy that agroforestry is just another method of increasing afforestation in Ireland rather than a method to aid farms in being more climate resilient, heighten livestock husbandry and increase biodiversity at a farm level. Such narrow focuses from policy regarding innovations has been recorded in previous studies using this coupled structural-functional analysis (Kebebe et al., 2015). As such, the researcher proposes the following goal.

- [G4] Remove or reduce the perceived risk of the re-designation requirement of the current agroforestry scheme.

Research conducted on the barriers to uptake of agroforestry in Ireland also identified specific policy failures that have been identified through this research study (Irwin et al., 2022, 2023). Although effort has been undertaken to address such barriers in the previous reform of the agroforestry scheme which occurred pre the interview stage and which included a monetary increase in the initial grant and a lengthening of the premium period from five to ten years, actors identified this scheme as remaining insufficient. Furthermore, there has been a failed effort to reduce or remove the perceived risk of the re-designation requirement of this scheme. Additionally, specific additional DAFM schemes have been identified as being in direct competition with agroforestry which may explain the relative low numbers of uptake of the agroforestry scheme. Furthermore, issue arises around terminology when agroforestry is being addressed in policy documents. In order to remove or reduce the impact of these policy failures, the researcher proposes the following goal.

- [G5] Continue to make the funding sources for agroforestry more attractive to farmers through the use of a more fluid design process for grant funded agroforestry or increasing the monetary incentive available such as payment for ecosystem goods and services.

Teagasc was identified as the main funding body for the research being undertaken leading to financial infrastructure failures. This monopoly in research may lead to misguidance through only researching within the organisations goals. More actors will prove beneficial to ensure this does not occur and to create a shared vision for the future development of agroforestry in Ireland, reducing directionality failures. As such, the researcher proposes the following goal.

- [G6] Increase engagement of actors in research to reduce the potential of misguidance from singular funding sources, ensure the presence of long-term research studies, and increase directionality.

Research failures were also identified including the insufficient number of research sites and the failure of this research to reach capacity. Similar findings were observed following analysis of the systemic problems affecting co-innovation in agriculture in New Zealand (Turner et al., 2016). A number of knowledge infrastructure failures were identified in this study. Firstly, due to the long-term nature of afforestation, the potential for adequate research to be conducted is greatly reduced. Research sites are few,

with Loughgall in the north being the only established research site on the island of Ireland. Middle aged sites are lacking due to previous research sites being cleared to allow for alternative research to take place. This has created a research platform dominated by recently established sites with robust data from a long-term study limited to one location with specific management practices, tree types, climatic conditions and soil conditions reducing its transferability. Furthermore, specific actors identified a demand for further research to be undertaken such as on design to ensure the right tree in the right place which can inform the design of future grant schemes. Demand was also identified for research on the carbon capture capacity of agroforestry systems and the potential for payment for ecosystem goods and services. Additionally, economic evaluations of altering the land use to enable agroforestry uptake was also identified as lacking. In order to resolve these research failures, the researcher proposes the following goal.

- [G7] Ensure more research is conducted on agroforestry in an Irish context including conducting in-depth economic evaluations such as through the creation of a farming systems economic value decision support tool.

The lack of research undertaken on the current market structure is an additional financial failure that must be addressed. Although the majority of actors identified consumers as being willing to pay for products from agroforestry farms and perceived a demand for such products, these are only speculations with no robust consumer study being conducted. Furthermore, in order to develop a market for agroforestry products, accreditation and a label must first be created that can be easily recognisable. These demand articulation failures must first be addressed before monetary and physical effort on the creation of such markets be exerted. As such, the following goal is proposed.

- [G8] Establish a market for agroforestry products through first identifying and learning from consumer perceptions and requirements.

Similarly to this study, social norms were observed to play a key role in altering management practices and adoption of new techniques at farm level in a study conducted by Irwin et al. (2023). As such, agroforestry uptake may benefit through the use of a bottom-up approach to innovation adoption. However, the current level of peer-to-peer knowledge exchange on agroforestry is lacking. The farmers interviewed did not exhibit sufficient knowledge of the practice nor did their communication pathways lead to the Irish Agroforestry Forum who is the main disseminator of knowledge regarding agroforestry in Ireland. Furthermore, current hard and soft institutions are impeding the transfer of positive perceptions and are instead strengthening the negative connotations that are currently engrained in the farming community regarding agroforestry. This is further reinforced through deficiencies in the current knowledge infrastructure [B1] in combination with strong network failures [B3] and weak network failures [B3]. Increasing peer-to-peer learning may prove invaluable in increasing awareness and uptake of agroforestry in Ireland; the following goal is therefore proposed.

- [G9] Encourage peer to peer learning through “signpost farms”, incentivised on-site training days and the creation of local knowledge transfer groups.

As stated above, the research has concluded in a number of failures of the current agroforestry innovation system in Ireland. The combination of such failures has resulted in an innovation system that can be regarded as bordering on defunct. However, it can be argued that each of these failures can be attributed to the one overarching failure: no-one is taking responsibility for agroforestry in Ireland. As the results indicate, agroforestry is a relatively new innovation in Ireland and as such has not been engrained into the agricultural sector nor the forestry sector; neither sector has taken, nor intends to take, responsibility for this land management practice. This is a major barrier to agroforestry; the failure of specific groups outside the Irish Agroforestry Forum (IAF), and to a certain extent the forest service, to take responsibility for agroforestry or to claim it as a land management option under their sectoral remit allows agroforestry to remain in “no-mans’ land” with no promotion nor inclusion within their suite of goals. This disconnect between the agricultural and forestry sectors in Ireland is engrained in history and may be explained through a lack of farm forestry tradition in Ireland (Malone, 2009; Stoettner and Ní Dhubháin, 2019), in combination with a mistrust in forestry (Flechard et al., 2007). As agroforestry is the combination of both agriculture and forestry, it can be argued that both sectors play an equally vital role in its uptake.

If the goals identified above are adhered to, agroforestry has the potential to be a vital contributor to Ireland reaching its goal of 18 % forestry cover by 2046. Furthermore, heightened tree cover on farms leads to heightened greenhouse gas absorption and carbon sequestration in conjunction with creating an end product that requires a lower carbon footprint; agroforestry therefore has the potential to aid Ireland in reaching its emissions reduction targets. However, in order to

successfully reach each of the goals proposed above, each sector must first take responsibility for increasing agroforestry uptake. More research is needed in order to determine appropriate methods to encourage each sector to take an equal share of the responsibility for agroforestry uptake in Ireland.

### CRediT authorship contribution statement

**Rachel Irwin:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation. **Ian Short:** Writing – review & editing, Supervision. **Aine Ní Dhubháin:** Writing – review & editing, Supervision.

### Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

### Acknowledgements

This research was funded under the Teagasc Walsh Scholarship Program, no. 2020026. The authors would like to thank all participants who contributed to the interviews.

### Appendices. 7

#### 7.1 Appendix 1: Interview Questions

##### *Innovation Study Interview Questions:*

Just to let you know, all the information gathered will be anonymous and questions will relate to agroforestry within Ireland. Agroforestry is a land-use system where trees are incorporated alongside crops and/or livestock. Agroforestry systems include linear systems such as hedgerows and buffer strips, grazed woodlands or scattered trees within pasture whereby the trees are managed as part of the farm system. The results of this study will be collated and analysed to aid policy and help create guidelines for policy makers.

##### *Section A: Background information*

1. Can you tell me about your role within [organisation/company]?
2. How long have you had this role?
3. How influential is your organisation/company in regard to Irish agriculture?
4. Does your organisation play a role in agroforestry? If yes, what is that role? If not, why?
5. Can you tell me about your knowledge of and experiences with agroforestry?
6. What are your personal views regarding agroforestry such as its growth potential and risks?

##### *Section B: Structural Analysis*

1. What other organisations or people do you exchange information regarding agroforestry with? (If they don't exchange information, why not? *Skip to Q4*)
2. What information do you exchange?
3. How often does this information exchange occur and can you describe the relationship (direction of the flow of the information - unidirectional/multidirectional)?
4. Do you think there are certain companies and organisations that should be exchanging information on agroforestry that are currently not? Why do you think this is the case?
5. What do you think are the barriers to agroforestry uptake in Ireland?

*Section C: Functional Analysis**Function 1: Entrepreneurial activities.*

1. Do you know many farmers engaging in agroforestry in Ireland? Do they represent a wide geographical coverage and variety of practices?
2. What is the level of interest in adopting agroforestry practices amongst the farming community? Do farmers experiment with agroforestry (if not why not?)?
3. Do you think it is easy for farmers to convert to agroforestry? Do you think farmers have access to machinery and technology that allows them to adopt agroforestry practices?

*Function 2: Knowledge development.*

1. Is there enough research being undertaken on agroforestry in Ireland? If not, what areas need to be addressed?
2. Who is engaged in the research?
3. Who funds it and is it demand driven?

*Function 3: Knowledge dissemination.*

1. Is there information about agroforestry, including information regarding the grant aid, available to farmers? Is there information not available?
2. Is information regarding agroforestry easy to access by farmers and who provides this information?
3. Who do you think should be responsible to sharing knowledge of agroforestry to farmers?
4. Are there other farming practices that compete with agroforestry? How do they compete and what are their advantages and disadvantages?

*Function 4: Guidance of the search.* Interviewees will be asked whether they are aware of the grant aid available for agroforestry. If they are not aware of the following information will be given regarding the Grant/premium category (GPC) 11: this is the main grant aid available for agroforestry in Ireland. This scheme provides funding for combining evenly spaced trees with grazing and silage with an initial stocking rate of 400–1000 trees per hectare; acceptable trees include oak, cherry and sycamore with 15 % of fruit or nut producing trees such as apple or hazelnut. The minimum plot size is 0.5 ha. GPC 11 funds 80 % of the eligible costs of setting up the system with an additional fencing allowance of €600 or €450. The initial grant is paid in two instalments (€4215 and €1405) and an annual premium available for 5 years of €645 (for areas less than 10 ha) or €660 (for areas greater than 10 ha). Only grazing of young stock or sheep and silage making is permitted for the first 6–8 years during the spring and summer periods so long as adequate tree guards of 1.5m in height with two supporting posts are in place.

1. Does your organisation have a specific goal in relation to agroforestry in Ireland?
2. Are you aware of the current grant aid available to farmers? Do you think the current level of grant aid available to farmers is adequate?
3. Is there anything about the current legislation regarding forest land that influences the uptake of agroforestry?

4. Without grant aid do you think farmers would adopt agroforestry?

*Function 5: Market formation.*

1. Are you aware of any products currently available that come from farms engaging in agroforestry?
2. Can you tell me what products you think could come from agroforestry?
3. Do you think consumers would be more willing to buy animal products such as meat and eggs from farms engaging in agroforestry than from conventional farms?

*Function 6: Resources mobilisation.*

1. Do you believe that the companies/organisations/individuals you have identified have the capacity to facilitate the transition from conventional agriculture to agroforestry in Ireland?
2. What else is needed – who else should be active in this area? Do you think there are people involved that are not needed?

*Function 7: Creation of legitimacy (The creation of legitimacy reduces uncertainties and counteracts the resistance to change).*

1. Do you think landowners see agroforestry as being a viable land use option?
2. Is there resistance to agroforestry among farmers/landowners? If so why do you think this is?
3. Are there people or organisations that are working on increasing agroforestry uptake in Ireland? Do you think their work is helping to reduce this resistance to changing land-use by farmers?
4. Are there people or organisations that are working against agroforestry?

**Data availability**

The data that has been used is confidential.

**References**

- Aerni, P., Nichterlein, K., Rudgard, S., Sonnino, A., 2015. Making agricultural innovation systems (AIS) work for development in tropical countries. *Sustainability* 7 (1), 831–850. <https://doi.org/10.3390/su7010831>.
- Agwu, A.E., Dimelu, M.U., Madukwe, M.C., 2008. Innovation system approach to agricultural development: policy implications for agricultural extension delivery in Nigeria. *Afr. J. Biotechnol.* 7 (11), 1604–1611. <https://doi.org/10.5897/AJB08.289>.
- Anandajayasekeram, P., 2022. The role of agricultural R&D within the agricultural innovation systems framework. In: *Innovation in Small-Farm Agriculture*. CRC Press, pp. 75–87.
- Arnold, E., Bell, M., 2001. Some new ideas about research for development. Partnership at the Leading Edge: A Danish Vision for Knowledge. Research and Development, pp. 278–316. [http://www.technopolis-group.com/resources/downloads/reports/255\\_DANIDA.pdf](http://www.technopolis-group.com/resources/downloads/reports/255_DANIDA.pdf).
- Bank, W., 2006. *World Bank, 2006. Enhancing Agricultural Innovation: How to Go beyond the Strengthening of Research Systems*. World Bank, Washington.
- Braun, V., Clarke, V., 2012. Thematic Analysis. In: Cooper, H., Camic, P.M., Long, D.L., Panter, A.T., Rindskopf, D., Sher, K.J. (Eds.), *APA handbook of research methods in psychology*, Vol. 2. Research designs: Quantitative, qualitative, neuropsychological, and biological. American Psychological Association, pp. 57–71. <https://doi.org/10.1037/13620-004>.
- Busse, M., Schwerdtner, W., Siebert, R., Doernberg, A., Kuntosch, A., König, B., Bokelmann, W., 2015. Analysis of animal monitoring technologies in Germany from an innovation system perspective. *Agric. Syst.* 138, 55–65. <https://doi.org/10.1016/j.agsy.2015.05.009>.

- Chunhavuthiyanon, M., Intarakumnerd, P., 2014. The role of intermediaries in sectoral innovation system: the case of Thailand's food industry. *Int. J. Technol. Manag. Sustain. Dev.* 13 (1), 15–36.
- Conley, B.T.G., Udry, C.R., 2016. American economic association learning about a new technology. Pineapple in Ghana Author (s): Timothy G. Conley and Christopher R. Udry Source : *The American Economic Review*, Vol. 100, No. 1 (March 2010), pp. 35–69 *Am. Econ.* 100 (1), 35–69.
- Cunningham, P., Ramlogan, R., 2016. The impact of innovation networks. *Handbook of innovation policy impact*.
- Curran, E. personal communication. Note: Eugene Curran Is a Forestry Inspector for DAFM and Has Been Integral in Creating Schemes and Measures to Increase Agroforestry Adoption in Ireland.
- Department of Agriculture, F. and the M., 2022. Forest statistics Ireland 2022. <https://www.gov.ie/en/organisation/department-of-agriculture-food->
- Edquist, C., 2013. *Systems of Innovation: Technologies, Institutions and Organisations*. Routledge.
- Edquist, C., Johnson, B., 1997. *Institutions and Organisations in Systems of Innovation*. In C.
- FAO, 2014. *Building a Common Vision for Sustainable Food and Agriculture: Principles and Approaches*.
- Flechar, M.C., Carroll, M.S., Cohn, P.J., Ni Dhubhain, A., 2007. The changing relationships between forestry and the local community in rural northwestern Ireland. *Can. J. For. Res.* 37 (10), 1999–2009.
- Foresight, U.K., 2011. *The Future of Food and Farming. Final Project Report*. The Government Office for Science, London.
- Hailu, M., Tolossa, D., Girma, A., Kassa, B., 2022. Exploration of systemic barriers to tef research and development in Central Ethiopia. *Coupled Struct.-Funct. Innov. Syst. Anal.* 37 (2), 211–222.
- Hall, A., Janssen, W.G., Pehu, E., Rajalahti, R., 2006a. *Enhancing Agricultural Innovation: How to Go beyond the Strengthening of Research Systems*. World Bank, Washington.
- Hall, A., Mytelka, L.K., Oyeyinka, B., 2006b. *Concepts and Guidelines for Diagnostic Assessments of Agricultural Innovation Capacity*.
- Hartwich, F., Scheidegger, U., 2010. Fostering innovation networks: the missing piece in rural development? *Rural Dev. News* 1, 70–75.
- Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M., 2007. Functions of innovation systems: a new approach for analysing technological change. *Technol. Forecast. Soc. Change* 74 (4), 413–432. <https://doi.org/10.1016/j.techfore.2006.03.002>.
- Hermans, F., Van Apeldoorn, D., Stuiver, M., Kok, K., 2013. Niches and networks: explaining network evolution through niche formation processes. *Res. Pol.* 42 (3), 613–623. <https://doi.org/10.1016/j.respol.2012.10.004>.
- Irwin, R., Ni, A., Short, L., 2022. Irish dairy and drystock farmers' attitudes and perceptions to planting trees and adopting agroforestry practices on their land. *Environ. Chall.* 9 (July), 100636. <https://doi.org/10.1016/j.envc.2022.100636>.
- Irwin, R., Short, L., Mohammadrezaei, M., Dhubháin, Á.N., 2023. Increasing tree cover on Irish dairy and drystock farms: the main attitudes, influential bodies and barriers that affect agroforestry uptake. *Environ. Sci. Pol.* 146, 76–89. <https://doi.org/10.1016/j.envsci.2023.03.022>.
- Jarský, V., 2015. Analysis of the sectoral innovation system for forestry of the Czech Republic. Does it even exist? *For. Pol. Econ.* 59, 56–65. <https://doi.org/10.1016/j.forpol.2015.05.012>.
- 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. Transit.* 24, 32–44. <https://doi.org/10.1016/j.eist.2016.10.001>.
- Kilcline, K., Dhubháin, Á.N., Heanue, K., O'Donoghue, C., Ryan, M., 2021. Addressing the challenge of wood mobilisation through a systemic innovation lens: the Irish forest sector innovation system. *For. Pol. Econ.* 128 (April). <https://doi.org/10.1016/j.forpol.2021.102461>.
- 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. In: Darnhofer, I., Gibbon, D., Dedieu (Eds.), *Farming Systems Research into 21st Century: The New Dynamic*. Springer Science, Business Media Dordrecht, p. 457.
- Klerkx, Laurens, Aarts, N., Leeuwis, C., 2010. Adaptive management in agricultural innovation systems: the interactions between innovation networks and their environment. *Agric. Syst.* 103 (6), 390–400. <https://doi.org/10.1016/j.agsy.2010.03.012>.
- Koasidis, K., Karamaneas, A., Nikas, A., Neofytou, H., Hermansen, E.A.T., Vaillancourt, K., Doukas, H., 2020. Many miles to Paris: A sectoral innovation system analysis of the transport sector in Norway and Canada in light of the Paris agreement. *Sustainability* 12 (14). <https://doi.org/10.3390/su12145832>.
- Kubeczko, K., Rametsteiner, E., Weiss, G., 2006. The role of sectoral and regional innovation systems in supporting innovations in forestry. *For. Pol. Econ.* 8 (7), 704–715. <https://doi.org/10.1016/j.forpol.2005.06.011>.
- Lamprinopoulou, 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>.
- Larsen, K., Kim, R., Theus, F. (Eds.), 2009. *Agribusiness and Innovation Systems in Africa*. World Bank Publications.
- Lawson, G.J., Brunori, A., Palma, J.H.N., Balaguer, F., 2016. Sustainable management criteria for Agroforestry in the European Union. 3rd European Agroforestry Conference 2016 Book of Abstract, pp. 375–378.
- Malone, J., 2009. *Factors Affecting Afforestation in Ireland in Recent Years*. Irish Government Paper, Dublin.
- Mercer, D.E., 2004. Adoption of agroforestry innovations in the tropics: a review. *Agrofor. Syst.* 61–62 (1–3), 311–328. <https://doi.org/10.1023/B:AGFO.0000029007.85754.70>.
- Minh, T.T., Economics, R., 2016. *Unpacking Systemic Problems and Blocking Mechanisms of a Regional Agricultural Innovation System : an Integrated Regional-Functional-Structural Analysis*, pp. 1–26.
- Moser, C.M., Barrett, C.B., 2006. The complex dynamics of smallholder technology adoption: the case of SRI in Madagascar. *Agric. Econ.* 35 (3), 373–388. <https://doi.org/10.1111/j.1574-0862.2006.00169.x>.
- Nair, P.K.R., Kumar, B.M., Nair, V.D., 2009. Agroforestry as a strategy for carbon sequestration. *J. Plant Nutr. Soil Sci.* 172 (1), 10–23. <https://doi.org/10.1002/jpln.200800030>.
- Neeson, E., 1991. *A History of Irish Forestry*. Lilliput Press Ltd.
- Pumariño, L., Sileshi, G.W., Gripenberg, S., Kaartinen, R., Barrios, E., Muchane, M.N., Midega, C., Jonsson, M., 2015. Effects of agroforestry on pest, disease and weed control: a meta-analysis. *Basic Appl. Ecol.* 16 (7), 573–582. <https://doi.org/10.1016/j.baee.2015.08.006>.
- Raskin, B., Osborn, S., 2019. *The agroforestry handbook – agroforestry for the UK*. Soil Assoc. Ltd.: Bristol. <https://www.soilassociation.org/farmers-growers/technicalinformation/agroforestry-on-your-farm/download-the-agroforestry-handbook/>.
- Richards, L., 1999. Data alive! the thinking behind NVivo. *Qual. Health Res.* 9 (3), 412–428. <https://doi.org/10.1177/104973239900900310>.
- Röling, N., 1990. The agricultural research-technology transfer interface: a knowledge systems perspective. In *Making the Link*. Agricultural Research and Technology Transfer in Developing Countries, pp. 1–42.
- Smits, R., Kuhlmann, S., 2004. The rise of systemic instruments in innovation policy. *Int. J. Foresight Innovation Policy* 1, 4–32.
- Spielman, D.J., Birner, R., 2008. How innovative is your agriculture? Using innovation indicators and benchmarks to strengthen national agricultural innovation systems. *Agric. Rural Dev.* 3–55.
- Spielman, D.J., Ekboir, J., Davis, K., Ochieng, C.M.O., 2008. An innovation systems perspective on strengthening agricultural education and training in sub-Saharan Africa. *Agric. Syst.* 98 (1), 1–9. <https://doi.org/10.1016/j.agsy.2008.03.004>.
- Stoettner, E.M., Ní Dhubháin, Á., 2019. The social networks of Irish private forest owners: an exploratory study. *For. Pol. Econ.* 99 (March 2017), 68–76. <https://doi.org/10.1016/j.forpol.2017.09.008>.
- 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>.
- Udawatta, R.P., Rankoth, L.M., Jose, S., 2019. Agroforestry and biodiversity. *Sustainability* 11 (10). <https://doi.org/10.3390/su11102879>.
- van Mierlo, B., Leeuwis, C., Smits, R., Woolthuis, R.K., 2010. Learning towards system innovation: evaluating a systemic instrument. *Technol. Forecast. Soc. Change* 77 (2), 318–334. <https://doi.org/10.1016/j.techfore.2009.08.004>.
- 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. Pol.* 41 (6), 1037–1047. <https://doi.org/10.1016/j.respol.2011.10.015>.
- Wieczorek, A.J., Hekkert, M.P., 2012. Systemic instruments for systemic innovation problems: a framework for policy makers and innovation scholars. *Sci. Publ. Pol.* 39 (1), 74–87. <https://doi.org/10.1093/scipol/scr008>.
- Woodland Trust, 2013. *Benefits of trees on dairy farms*. November. <https://www.woodlandtrust.org.uk/mediafile/100263169/rr-wt-71014-benefits-of-trees-on-dairy-farms.pdf?cb=5a63faf7c3dd4a4ebf0765d080f8ddcd>.
- Wuepper, D., Sauer, J., Kleemann, L., 2014. In: *Sustainable Intensification of Pineapple Farming in Ghana: Training and Complexity*. 1973, p. 31 undefined. <http://hdl.handle.net/10419/103980www.econstor.eu>.