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Review Article

# Forest carbon farming in Ireland: a scoping review of policy–practice misalignment in a low-forest agricultural system

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ABSTRACT

Ireland has ambitious targets for expanding tree cover and using forestry to support climate mitigation, biodiversity recovery and climate adaptation, yet forest cover remains approximately 11% and recent afforestation rates remain below national targets. This paper argues that the central challenge is not primarily a lack of technical pathways, but a policy–practice misalignment between carbon and biodiversity objectives, forestry scheme design, farmer decision-making and trusted delivery mechanisms. We conducted a scoping review following PRISMA-ScR guidance, screening 238 records, assessing 87 full texts and synthesizing 30 core studies, of which 21 were published during 2020–2025. The review shows that Ireland has substantial theoretical afforestation potential, including estimates of several hundred thousand hectares of potentially suitable land, but uptake is constrained by recurring barriers: land-use flexibility, farming identity, intergenerational lock-in, administrative complexity, uncertainty over long-term returns, biodiversity concerns and limited trust in policy stability. We synthesize these findings through a policy–practice misalignment framework that links four domains: ecological pathway suitability, scheme and governance design, farmer adoption constraints and trusted delivery mechanisms. This framework differs from a simple adoption-barrier list by showing how ecological, institutional and behavioural constraints reinforce each other. Participatory Action Research and Living Lab approaches are therefore positioned not as empirically established solutions in Ireland, but as implementation mechanisms that could test locally acceptable forestry models, monitoring burdens and incentive designs. The Irish case provides transferable lessons for other low-forest agricultural systems where carbon farming depends on aligning environmental ambition with landholder trust, practical feasibility and adaptive governance.

## Introduction

Ireland is at a critical juncture in its environmental policy trajectory. As a signatory to international climate agreements and EU biodiversity strategies, the nation must simultaneously address greenhouse gas emissions reduction, biodiversity loss, and climate adaptation while maintaining agricultural productivity and rural livelihoods. Forestry, particularly forest carbon farming, has emerged as a potential nexus solution capable of delivering multiple ecosystem services: carbon sequestration, biodiversity habitat provision, water quality regulation, and climate resilience enhancement (Guinness et al., 2020; Bishop et al., 2024). In this paper, forest carbon farming refers to land-management practices in forest and tree-based systems that are designed to increase carbon sequestration, reduce land-sector greenhouse-gas emissions, or maintain carbon storage, while potentially generating public or private rewards through policy schemes, carbon payments or other incentive mechanisms.

However, Ireland's forest cover remains among the lowest in Europe at approximately 11%, and afforestation rates have declined substantially in recent years despite ambitious policy targets (Farrelly et al., 2015; Adenaeuer et al., 2021). This implementation gap reflects complex socio-ecological challenges that include farmer reluctance, land availability constraints, policy fragmentation, and tensions between commercial forestry objectives and environmental conservation goals (Duesberg et al., 2013; Irwin et al., 2022).

The persistent implementation gap raises a sharper research problem: why does afforestation and forest-based carbon farming remain difficult to scale when policy support, technical forestry options and climate-policy arguments already exist? Existing studies document many separate barriers—economic uncertainty, land-use identity,

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biodiversity concerns, administrative complexity and low trust—but these factors are often treated as parallel themes rather than as interacting parts of a system failure. The challenge is therefore not only to map the literature, but to explain how policy design, ecological trade-offs and farmer adoption constraints combine to limit uptake.

Understanding this implementation gap requires attention to both behavioural and institutional dimensions of land-use change. Individual landholders make decisions under conditions of economic uncertainty, social norms, identity, perceived permanence and administrative burden. At the same time, these decisions are shaped by institutional design: grant rules, licensing procedures, advisory capacity, biodiversity safeguards, monitoring requirements and trust in long-term policy stability. We use the term policy–practice misalignment to describe situations where technically plausible forestry pathways are available, but policy instruments, ecological safeguards and landholder realities are not sufficiently aligned to enable implementation.

This scoping review addresses this knowledge gap by synthesizing evidence on forest carbon farming, biodiversity conservation, and climate adaptation in Ireland, paying particular attention to participatory approaches, stakeholder perspectives, and implementation barriers. The review is timely given Ireland's commitment to achieving net-zero emissions by 2050, the EU Biodiversity Strategy for 2030, and the growing recognition that effective environmental policy requires genuine stakeholder engagement and social license (Schenuit et al., 2021; Ó Foghlú, 2022).

This interpretation is consistent with behavioural and participatory theories of land-use change. From a behavioural perspective, adoption is shaped not only by financial incentives, but also by attitudes, perceived control, social norms, perceived compatibility with existing farming identity, and the complexity and reversibility of the innovation (Ajzen, 1991; Rogers, 2003). In this review, Living Labs are not treated as an already proven empirical solution for Irish forest carbon farming. Rather, they are examined as a possible implementation mechanism for testing whether proposed forestry pathways, monitoring requirements and incentive designs are workable for farmers, advisers, policymakers and communities before they are scaled.

This review addresses three research questions:

1. What explains the persistent gap between Irish forestry policy ambitions and low afforestation uptake?
2. How do biodiversity, climate-adaptation and carbon objectives interact with farmer adoption constraints?
3. What role could participatory and Living Lab-type approaches play in reducing policy–practice misalignment?

The contribution of the paper is a diagnostic synthesis rather than a simple inventory of themes. We use the Irish case to develop a policy–practice misalignment framework for forest carbon farming in low-forest agricultural systems.

## Methods

This scoping review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines (Tricco et al., 2018). The review protocol was developed a priori to ensure methodological rigor, transparency, and reproducibility. While formal protocol registration was not undertaken, the review adhered to established scoping review methodology (Peters et al., 2020).

A scoping review was appropriate because the research problem concerns the structure and interaction of heterogeneous evidence rather than the estimation of a single effect size. The included literature spans ecological studies, policy reports, stakeholder studies, modelling papers, advisory documents and participatory research. A meta-analysis would not be suitable because outcomes, methods, spatial scales and evidence types are not directly comparable. The purpose of the review was therefore to map, interpret and integrate evidence on how ecological, institutional and behavioural constraints interact in the Irish forest carbon farming system.

Inclusion criteria were based on a number of factors. Regarding geographic scope, we included studies focusing on Ireland (Republic of Ireland and Northern Ireland) or including Ireland as a case study within comparative research. In terms of the thematic scope, we included research addressing one or more of the following: forest carbon sequestration, afforestation, native woodland restoration, agroforestry, biodiversity conservation in forest contexts, climate adaptation through forestry, stakeholder perspectives on tree planting, participatory approaches to forest management, Living Lab methodologies in environmental contexts, and policy frameworks for forest carbon farming. The primary search focused on literature published between 2015 and 2025, reflecting recent policy developments after the Paris Agreement, the Climate Action Plan 2019 and the EU Green Deal. Earlier sources were included only where they were repeatedly cited in the recent literature, provided foundational evidence on Irish forestry adoption, or were necessary to interpret long-standing policy–practice barriers. We included among the publication types peer-reviewed journal articles, policy reports, government documents, technical reports, conference proceedings, and doctoral dissertations, all of which were published in the English language.

We excluded studies with no relevance to Ireland or Irish policy contexts; research focusing exclusively on non-forest ecosystems (e.g. peatlands, grasslands) without a forestry component; anything published prior to 2015 (unless a seminal work cited within one or more of the included studies); items published in languages other than English; and publications that lacked empirical or policy analysis content, such as opinion pieces, editorials, and commentaries.

The primary publication window was 2015–2025. The search was last updated in December 2025. Earlier sources were included only where they were repeatedly cited in recent literature, provided foundational evidence on Irish forestry adoption, or were necessary to interpret long-standing policy–practice barriers. The detailed synthesis included 30 core studies published between 2002 and 2025. The primary search window was 2015–2025, while older studies were retained only as foundational evidence for long-standing adoption, community or policy barriers.

As search strategy, we employed Boolean operators and combined terms from several clusters (Table 1).

Search strings combined the geographic cluster with at least one forestry-related term and at least one additional thematic cluster related to carbon, biodiversity, climate adaptation, participation or policy. For example, searches combined Ireland-related terms with afforestation/forestry terms and additional terms such as carbon farming, biodiversity, agroforestry, stakeholder, policy, Living Lab or climate adaptation.

**Table 1**
Search terms used.

| | |
|---|---|
| Geographic terms | "Ireland" OR "Irish" OR "Republic of Ireland" OR "Northern Ireland" |
| Forestry terms | "forest" OR "afforestation" OR "reforestation" OR "woodland" OR "tree planting" OR "agroforestry" OR "silviculture" OR "native woodland" |
| Carbon terms | "carbon" OR "carbon sequestration" OR "carbon farming" OR "carbon storage" OR "greenhouse gas" OR "GHG" OR "climate mitigation" |
| Biodiversity terms | "biodiversity" OR "ecosystem services" OR "habitat" OR "species" OR "conservation" OR "nature-based solutions" OR "NBS" |
| Climate adaptation terms | "climate adaptation" OR "climate resilience" OR "climate change adaptation" OR "resilience" |
| Participatory terms | "Living Lab" OR "participatory" OR "co-creation" OR "stakeholder" OR "community" OR "engagement" OR "social license" |
| Policy terms | "policy" OR "governance" OR "implementation" OR "incentive" OR "subsidy" OR "scheme" |

This approach ensured that included sources were both geographically relevant and thematically connected to forest carbon farming or its implementation context.

We also hand-searched (snowball sampled) reference lists of key included studies to identify additional relevant sources.

The selection process followed a two-stage screening approach. In Stage 1 (title and abstract screening) we imported all retrieved records into a reference management system and de-duplicated. Two reviewers independently screened titles and abstracts against the eligibility criteria. Conflicts were resolved through discussion and, where necessary, consultation with a third reviewer. Records deemed potentially relevant by either reviewer were advanced to full-text screening. In Stage 2 (full-text screening) we retrieved the full texts of potentially relevant records and assessed them against the eligibility criteria. We documented the reasons for any exclusions (e.g. wrong geography, focus, or publication type) and made final inclusion decisions by reviewer consensus.

We developed a standardized data charting form and piloted it on a sample of five included studies. We iteratively refined the form to ensure comprehensive and consistent data extraction. Data charting was then conducted independently by two reviewers, with regular calibration meetings to maintain consistency. The policy–practice misalignment framework was then developed by comparing how the five coded domains interacted across the included studies. A finding was treated as part of the misalignment framework when evidence showed that a technically feasible pathway was constrained by at least one institutional, behavioural or delivery-related barrier.

Given the heterogeneity of study designs, methodologies, and outcome measures, we employed a narrative synthesis approach rather than a quantitative meta-analysis. The synthesis process involved several steps:

- Descriptive numerical summary—characterizing the evidence base by publication year, study design, geographic focus, and thematic content;
- Thematic analysis—identifying major themes and subthemes through iterative coding of extracted data, and refining those themes through team discussion to ensure coherence and comprehensiveness;
- Comparative analysis—examining convergence and divergence in findings across studies, particularly regarding stakeholder perspectives, policy effectiveness, and biodiversity–carbon trade-offs;
- Gap analysis—identifying underexplored topics, methodological limitations, and areas requiring further research;
- Integration with Living Lab framework—assessing the extent to which existing research incorporates participatory, co-creative, and community-engaged approaches.

The thematic analysis used a hybrid deductive–inductive coding approach. Deductively, we coded each source against five analytical domains derived from the research questions: (1) ecological pathway and carbon/biodiversity implications; (2) policy and scheme design; (3) farmer/landholder adoption constraints; (4) institutional delivery and advisory capacity; and (5) participatory or Living Lab-type mechanisms. Inductively, we then coded recurring subthemes emerging from the literature, including land-use lock-in, farming identity, perceived permanence, administrative burden, social license, biodiversity safeguards, agroforestry compatibility, and uncertainty regarding long-term returns. The final synthesis was organized around interactions among these domains rather than around individual studies alone.

A small number of conceptual or comparative sources on participatory monitoring and Living Lab approaches were used to interpret the Irish evidence, but were not treated as Ireland-specific empirical evidence unless they included an Irish case. We now distinguish these conceptual sources from the 30 core Ireland-focused studies in the synthesis tables.

The systematic search identified 238 unique publications after de-duplication. Following title and abstract screening, 87 records were advanced to full-text review. Of these, 30 studies met all eligibility criteria and were included in the detailed synthesis. The primary reasons for exclusion at the full-text stage were insufficient focus on Ireland (n = 28), lack of relevance to forest carbon farming or biodiversity (n = 19), and publication type not meeting the inclusion criteria (n = 10). Fig. 1 presents a PRISMA flow diagram summarizing the study selection process.

We prioritized transparency in synthesis, acknowledging limitations in the evidence base and avoiding overgeneralization from limited or conflicting findings. Because this was a scoping review of heterogeneous evidence, we did not conduct a formal risk-of-bias appraisal or evidence-grading exercise. Instead, we treated the strength of evidence cautiously by distinguishing between peer-reviewed empirical studies, modelling studies, policy reports, technical documents and conceptual or participatory sources. The review therefore identifies explanatory patterns and implementation constraints, but does not claim that all included sources provide the same level of evidential strength.

## Results

The synthesis shows that Ireland's forest carbon farming challenge is not defined by one missing instrument, but by the interaction of ecological pathway constraints, policy design, farmer adoption barriers and weakly institutionalized trust-building mechanisms. The 30 core studies indicate four cross-cutting findings: (1) technically plausible pathways exist, including native woodland restoration, agroforestry, mixed systems and commercial forestry with safeguards; (2) land availability does not automatically translate into landholder willingness; (3) financial incentives are necessary but insufficient without flexibility, advice and legitimacy; and (4) Living Lab-type approaches are discussed as potential mechanisms for implementation testing, but remain weakly documented in Irish forestry practice.Regarding the publication timeline, the 30 included studies span 2002–2025, with a notable concentration in recent years: there are 2 studies from 2002 to 2010, 7 studies from 2011 to 2019, and 21 studies from 2020 to 2025. This temporal distribution reflects the growing policy and research attention being paid to climate mitigation, biodiversity conservation, and nature-based solutions (NBS) in the post–Paris Agreement era.

Many of the included studies (Table 2) address multiple themes, reflecting the interconnected nature of forest carbon farming, biodiversity, and climate adaptation. Table 2 presents the main themes identified in this review and the included studies that address each theme. This thematic organization reflects the structure of the results synthesis and helps identify evidence clusters and research gaps.

The included sources comprised peer-reviewed empirical studies, modelling papers, policy reviews, technical reports, dissertations and selected conceptual sources on participatory implementation.

We will now present the results of the analysis in more depth, for each identified theme in turn.

To move beyond a descriptive thematic review, we organized the findings through a policy–practice misalignment framework (Fig. 2). The framework interprets low afforestation and limited forest carbon farming uptake as the outcome of interactions among four domains: ecological pathway suitability, policy and scheme design, farmer adoption constraints, and participatory delivery mechanisms. The framework shows that technically feasible pathways may fail if they are perceived as administratively complex, economically uncertain, ecologically inappropriate, or incompatible with farming identity and land-use flexibility.

### *Community engagement and participatory approaches in living lab contexts*

The reviewed literature provides limited direct evidence of Living

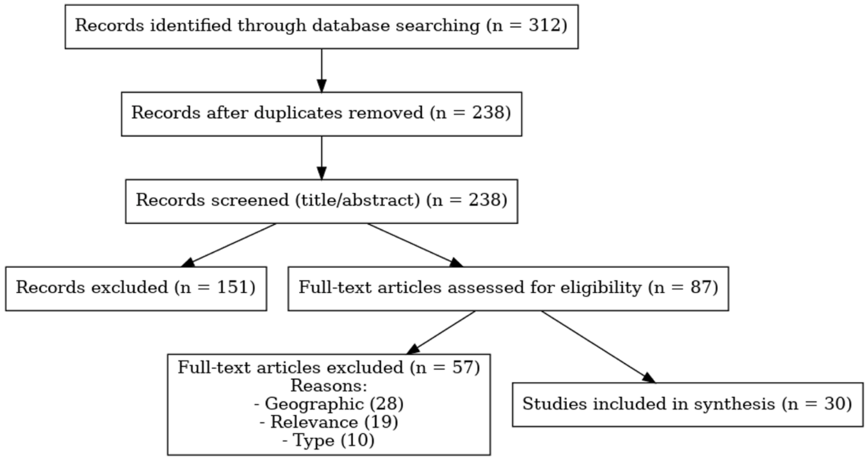


**Fig. 1.** PRISMA flow diagram illustrating the study selection process.

**Table 2**
Thematic distribution of included studies.

| Main theme | Key references (included studies) |
|---|---|
| Community engagement and Living Lab approaches | Torabi, 2015; Guinness et al., 2020; Adenaeuer et al., 2021; Ó Foghlú, 2022; Molloy et al., 2024; Lapin et al., 2025 |
| Policy implementation frameworks | McAree, 2002; Biber et al., 2020; Guinness et al., 2020; Adenaeuer et al., 2021; Schenuit et al., 2021; Bishop et al., 2024; Carlier et al., 2024; Knapp et al., 2024; Matthews and O'Neill, 2025; Olave et al., 2025 |
| Ecological monitoring and assessment methods | McAree, 2002; Farrelly et al., 2015; Biber et al., 2020; Lundholm et al., 2020; Adenaeuer et al., 2021; Farrelly et al., 2022; Murphy et al., 2023; Byrne et al., 2024; Carlier et al., 2024 |
| Carbon sequestration and forest carbon farming | Torabi, 2015; Biber et al., 2020; Duffy et al., 2020; Guinness et al., 2020; Adenaeuer et al., 2021; Schenuit et al., 2021; Bishop et al., 2024; Byrne et al., 2024; Carlier et al., 2024; Jarmain et al., 2024; Olave et al., 2025 |
| Biodiversity conservation | McAree, 2002; Farrelly et al., 2015; Torabi, 2015; Biber et al., 2020; Guinness et al., 2020; Lundholm et al., 2020; Adenaeuer et al., 2021; Farrelly et al., 2022; Carlier et al., 2024; Molloy et al., 2024 |
| Climate adaptation | Andersson et al., 2017; Biber et al., 2020; Lundholm et al., 2020; Adenaeuer et al., 2021; Best et al., 2022; Murphy et al., 2023; Byrne et al., 2024; Carlier et al., 2024; Molloy et al., 2024 |
| Native woodland restoration | McAree, 2002; Farrelly et al., 2015; Torabi, 2015; Guinness et al., 2020; Adenaeuer et al., 2021; Farrelly et al., 2022; Ó Foghlú, 2022; Molloy et al., 2024; Lapin et al., 2025 |
| Commercial forestry schemes | McAree, 2002; Farrelly et al., 2015; Biber et al., 2020; Duffy et al., 2020; Adenaeuer et al., 2021; Farrelly et al., 2022; Jarmain et al., 2024 |
| Stakeholder perspectives (farmers/landowners) | Ní Dhubháin et al., 2009; Duesberg et al., 2013; Torabi, 2015; Andersson et al., 2017; Guinness et al., 2020; Adenaeuer et al., 2021; Best et al., 2022; Irwin et al., 2022; Ó Foghlú, 2022; Murphy et al., 2023; Knapp, Byrne et al., 2024, 2024; Lapin et al., 2025; Olave et al., 2025 |
| Afforestation processes and land availability | Duesberg et al., 2013; Farrelly et al., 2015; Duffy et al., 2020; Adenaeuer et al., 2021; Farrelly et al., 2022; Irwin et al., 2022; Bishop et al., 2024; Matthews and O'Neill, 2025 |

*Note:* The table reports the 30 core Ireland-focused studies. Selected conceptual sources on participatory monitoring and Living Lab approaches are discussed separately where they help interpret the implementation implications, but they are not counted as Ireland-specific empirical evidence.

Lab implementation in Irish forest carbon farming. Only a small number

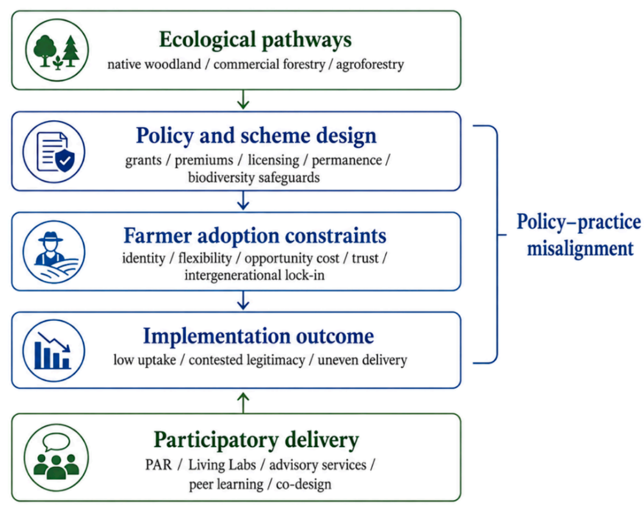


**Fig. 2.** Policy–practice misalignment framework for forest carbon farming in Ireland. The framework links ecological pathway choices, policy design, farmer adoption constraints and participatory delivery mechanisms. The central implementation problem is not absence of forestry options, but misalignment between environmental objectives and landholder realities.

of sources explicitly discuss Living Lab or participatory-monitoring approaches, and some of these are conceptual or comparative rather than Ireland-specific (Evans et al., 2016; Guinness et al., 2020). The stronger evidence concerns a broader pattern: Irish forestry policy has increasingly recognized the need for stakeholder engagement, social licence and local participation, but genuine co-design of scheme rules, monitoring requirements or acceptable land-use models remains weakly institutionalized.

Irish and comparative sources point to several recurring participation barriers: limited local influence over forestry decisions, uneven power between public agencies, commercial interests and small landholders, insufficient funding for facilitation, and uncertainty over how participatory pilots would be evaluated (Fléchard et al., 2006, 2007; Ó Foghlú, 2022; Lapin et al., 2025). These findings support the use of Living Labs as a possible implementation-testing mechanism, but not as an empirically established solution. In this paper, the Living Lab perspective is therefore used cautiously: it identifies where co-design and participatory monitoring could be tested, rather than claiming that such approaches already structure Irish forest carbon farming.

Based on our analysis of the selected studies, we prepared a comprehensive illustration of the afforestation process in Ireland

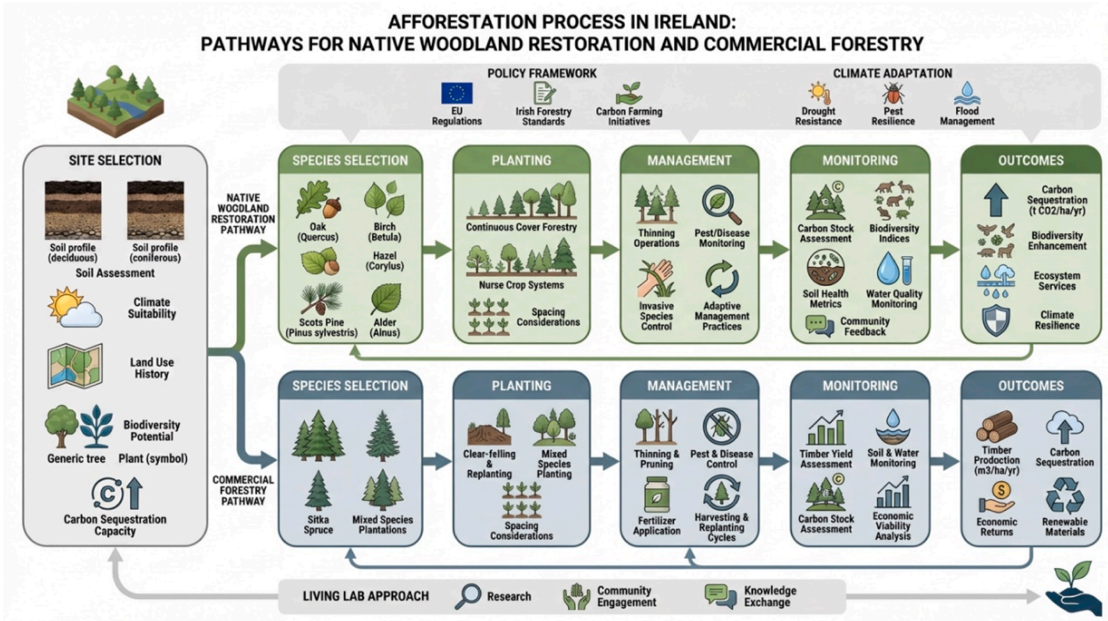


**Fig. 3.** Afforestation process in Ireland—current and potential pathways.

(Fig. 3). It shows two parallel pathways: native woodland restoration (upper pathway) and commercial forestry (lower pathway). The diagram presents six sequential stages from site selection through to outcomes, incorporating Living Lab approaches, community engagement, policy frameworks, and multi-stakeholder perspectives. The native woodland pathway emphasizes biodiversity conservation, climate adaptation, and community participation, while the commercial forestry pathway focuses on timber production with carbon sequestration co-benefits. Both pathways demonstrate the kind of integration of ecological monitoring, adaptive management, and policy implementation frameworks that is essential for successful forest carbon farming in Ireland.

Synthesis statement: Participatory approaches are recognized as relevant to Irish forest carbon farming, but the evidence shows a gap between consultation and genuine co-design. Living Labs should therefore be interpreted as a proposed implementation testbed for policy–practice alignment, not as an already established governance model in Ireland.

*Policy implementation frameworks for forest carbon farming*

The policy evidence reveals a clear implementation paradox: Ireland has substantial policy ambition, public funding and technical forestry options, yet afforestation remains below target. Across the reviewed studies, this gap is explained by interacting constraints rather than by one missing incentive.

First, financial incentives are important but do not fully offset opportunity costs, especially where agricultural production remains profitable or where landholders perceive forestry as reducing long-term flexibility (Adenaeuer et al., 2021; Irwin et al., 2022; Knapp et al., 2024). Second, policy fragmentation limits implementation because forestry, agriculture, biodiversity and climate policy often operate through separate instruments, targets and administrative systems (Guinness et al., 2020; Bishop et al., 2024; Carlier et al., 2024). Third, biodiversity safeguards and carbon objectives are not always linked to transparent monitoring of outcomes, which weakens trust in whether schemes deliver their stated environmental benefits (McAree, 2002; Farrelly et al., 2022). Fourth, agroforestry and smaller-scale tree-cover options remain institutionally underdeveloped despite their potential to align carbon sequestration with continued agricultural use (Irwin et al., 2022; Olave et al., 2025).

This combination of constraints is the core policy–practice misalignment identified in the review: the policy system offers incentives for forestry, but the design of those incentives does not yet sufficiently match farmer decision-making, biodiversity legitimacy, administrative feasibility and long-term confidence.

*Ecological monitoring and assessment methods*

Robust ecological monitoring is essential for assessing the effectiveness of forest carbon farming in delivering carbon, biodiversity, and climate adaptation outcomes. However, the evidence reveals significant gaps in monitoring systems and methodological standardization in Ireland.

Byrne et al. (2024) present the ADAPTForRes project, which assesses forest resilience and carbon dynamics across different Irish forest types. The project employs field measurements, remote sensing, and process-based modeling to quantify carbon stocks and fluxes in native woodlands, mixed-species forests, and conifer plantations. Preliminary findings indicate substantial variation in carbon sequestration rates depending on species composition, stand age, site conditions, and management practices. This work highlights the need for forest-type-specific carbon accounting rather than reliance on generic national averages.

In their discussion of strategies for creating and managing forests for carbon from an Irish perspective, Jarmain et al. (2024) emphasize the importance of whole-life-cycle carbon accounting that includes establishment emissions, ongoing sequestration, harvesting impacts, and wood product carbon storage. They note that current policy frameworks often focus narrowly on standing biomass carbon, neglecting soil carbon dynamics and the fate of harvested wood products. This incomplete accounting may lead to overestimation of net climate benefits, particularly for short-rotation commercial forestry.

Duffy et al. (2020) model afforestation as a strategy for replacing livestock emissions with carbon sequestration. They find that converting marginal agricultural land to forestry can deliver net climate benefits, although outcomes depend critically on site selection: afforestation on high-carbon soils (peatlands or organic-rich soils) may result in net carbon losses due to soil disturbance, whereas afforestation on mineral soils typically yields positive carbon outcomes. This underscores the need for spatially explicit carbon assessment tools to guide afforestation site selection and avoid maladaptive practices.

In reviewing the Forest Service Biodiversity Plan, McAree (2002) outlines biodiversity monitoring requirements such as pre-planting ecological surveys, compliance inspections, and periodic biodiversity audits. However, subsequent reviews indicate that systematic biodiversity monitoring in Ireland's grant-aided forests remains limited. For instance, Farrelly et al. (2022) note that, while Ireland has made progress in forest inventory and carbon accounting, biodiversity monitoring systems lag behind, and long-term data are scarce on species richness, habitat quality, and ecosystem function in afforested landscapes.

Carlier et al. (2024) employ ecosystem service modeling to assess biodiversity outcomes of integrated agri-environment and forestry measures. Using habitat suitability indices and species distribution models, their approach demonstrates the potential of spatial modeling to predict biodiversity responses to land-use change. However, the authors acknowledge that model validation requires field-based monitoring data, which are currently sparse in Ireland.

Analysis of forest biodiversity, carbon sequestration, and wood production trade-offs across ten European forest landscapes, including one in Ireland, for Biber et al. (2020), reveals that maximizing carbon sequestration through intensive plantation forestry often comes at the cost of biodiversity. In contrast, management strategies that prioritize biodiversity (e.g. continuous-cover forestry, mixed native species plantings, retention of deadwood) may reduce short-term carbon accumulation but enhance long-term resilience and ecosystem multifunctionality. This study underscores the need for monitoring systems that track multiple outcomes simultaneously, rather than optimizing for a single objective.

In *Ireland's climate change assessment – Volume 3: Being prepared for Ireland's future climate*, Murphy et al. (2023) analyze how vulnerable forests are to climate change impacts such as increased storm frequency, drought stress, pest/disease outbreaks, and wildfire risk. They emphasize the need for adaptive forest management strategies and monitoring systems that track forest health, resilience indicators, and climate-related disturbances. However, they note that operational monitoring of climate adaptation outcomes (e.g. the condition of Irish forests under extreme weather events) remains limited.

Lundholm et al. (2020) use a strategic forest management decision support system to evaluate the impact of future climate change and bioeconomy scenarios on forest ecosystem services. Their modeling integrates climate projections, forest growth models, and ecosystem service assessments to explore management strategies under uncertainty. The analysis highlights that climate change will alter optimal species composition and management regimes in Irish forests, necessitating adaptive monitoring systems that can detect early warnings of climate stress (e.g. drought impacts, pest outbreaks) and inform timely management adjustments.

In their review of achievements in forest research in Ireland from 1960 to 2021, Farrelly et al. (2022) note substantial progress in areas like growth and yield modeling, timber quality assessment, and national forest inventory methods. However, they identify critical gaps in integrated monitoring frameworks that simultaneously track carbon, biodiversity, water quality, soil health, and social outcomes. They advocate for establishing long-term ecological research sites and adopting standardized monitoring protocols that are aligned with international frameworks (e.g. Forest Europe indicators, United Nations Sustainable Development Goals (UN SDGs)).

In summary, while Ireland has developed sophisticated carbon inventory systems for forestry, biodiversity and climate adaptation monitoring remain underdeveloped and fragmented across agencies and projects. There is limited coordination or data sharing among different monitoring initiatives, and few programs track multiple ecosystem services or social outcomes in tandem. Establishing comprehensive, long-term monitoring systems that cover carbon, biodiversity, and social metrics will be essential for adaptive management and evidence-based policy refinement. The evidence also highlights the need for participatory monitoring approaches that engage landowners, local communities, and practitioners in data collection and interpretation (as suggested by Evans et al., 2016), to build trust and incorporate local knowledge into monitoring processes.

*Stakeholder perspectives: farmers, landowners, policymakers, and conservation scientists*

Understanding the various stakeholder perspectives is critical if effective and socially acceptable forest carbon farming policies are to be designed. The evidence base provides rich insights into the attitudes, motivations, and concerns of diverse stakeholders, revealing significant tensions as well as opportunities for improved engagement.

Through their national survey of Irish farmers' goals and values regarding afforestation, Duesberg et al. (2013) find that the decision whether to plant (or not) is shaped by multiple factors, beyond financial considerations, which they group into five themes. First, in relation to identity and tradition, they reveal that many farmers view forestry as incompatible with a farming identity and agricultural heritage. They highlight a common sentiment — "Once you plant, you're no longer a farmer"—that reflects many farmers' deep cultural resistance to converting farmland to forests. Second, regarding flexibility and optionality, Duesberg et al. (2013) explain that farmers value highly the ability to adapt their land use to suit changing circumstances (e.g. market conditions, family needs, policy shifts), and so they see the commitment of 20 years or more required by forestry grant schemes as restrictive, and an unacceptable loss of future flexibility. Under the afforestation programme, forestry represents a permanent land-use change rather than a time-limited commitment, which many farmers perceive as restrictive and as a significant loss of future flexibility. Third are intergenerational considerations, which also link to flexibility: many of today's family farmers intend to pass their farms on to their children, and so they are wary about signing up to anything, such as an afforestation scheme, that might constrain their children's options in the future. Fourth, regarding landscape and aesthetics, the study reveals that some farmers feel a particular attachment to open agricultural landscapes; they therefore perceive large-scale forestry as something likely to diminish the quality and rural character of those landscapes. And finally, in relation to financial uncertainty, while forestry grants and annual premiums are attractive, farmers are skeptical about long-term policy stability and worry about possible volatility in the timber market decades in the future.

Irwin et al. (2022) examine attitudes of Irish dairy and drystock (beef/sheep) farmers toward tree planting and agroforestry. They find that dairy farmers are particularly resistant due to concerns about disrupting intensive production systems, reducing livestock carrying capacity, and complicating farm operations. Drystock farmers show somewhat greater openness than dairy farmers—especially with regard to planting on small areas of marginal land—but they are still concerned about administrative complexity, lack of technical advice, and the uncertainty surrounding the profitability of agroforestry. Both groups emphasize the need for flexible, farm-scale-appropriate tree planting schemes rather than one-size-fits-all approaches.

Exploring drivers of agroforestry adoption in Northern Ireland, Olave et al. (2025) identify key motivations—including environmental stewardship, farm diversification, and carbon benefits—but also barriers such as lack of knowledge, limited advisory support, policy uncertainty, and concerns that planting trees might jeopardize eligibility for agricultural subsidies. Farmers stress the importance of demonstration farms, peer learning networks, and accessible technical guidance. This study highlights that agroforestry adoption is not simply a matter of financial incentives; it requires comprehensive support systems, including knowledge transfer, risk mitigation measures, and long-term policy commitments.

Ní Dhubháin et al. (2009) examine stakeholder perceptions of forestry in two rural Irish case study areas, revealing diverse and sometimes conflicting views. While some community members value forestry for providing employment, recreation, and environmental benefits, others are concerned about landscape change, loss of agricultural land, reduced community vitality, and the fact that profits often flow to outside investors. This research underscores that forestry impacts are perceived differently across stakeholder groups, and effective engagement must acknowledge and address these varied perspectives.

The case studies by Fléchard et al. (2006, 2007) document evolving relationships between forestry and local communities in rural north-western Ireland. Early waves of afforestation in the 1980s–1990s generated a fair amount of community opposition as there was minimal consultation and people felt that the forests would have a negative impact on their local environment and way of life. More recent efforts show some improvements, with increased community consultation, but genuine participatory decision-making remains limited. Communities emphasize the need for local employment opportunities, recreational access to forest lands, and transparent governance in forestry development.

Ó Foghlú's (2022) analysis of social license reiterates that successful afforestation requires building trust through transparent communication, respecting local knowledge and values, and ensuring tangible local benefits. While legal permission and financial incentives are necessary to implement forestry projects, they are not sufficient on their own; forestry initiatives must also earn community acceptance and support. This entails ongoing dialogue, responsiveness to community concerns, and equitable sharing of benefits.

Direct research on Irish policymakers' views is limited in the reviewed literature, but policy documents and stakeholder analyses (e.g. Guinness et al., 2020; Knapp et al., 2024; Matthews and O'Neill, 2025) suggest several priorities and tensions. In relation to climate targets, policymakers often emphasize afforestation as being essential for meeting national climate commitments; the tendency is to view forestry as a cost-effective carbon sink. In terms of economic considerations, balancing agricultural productivity and rural livelihoods with environmental objectives creates policy tensions, given the political influence of the agricultural sector and farming lobby. There is also recognition of the persistent gap between afforestation targets and actual planting rates; such implementation challenges are commonly attributed to farmer reluctance, limited land availability, and bureaucratic or licensing hurdles. Lastly, regarding biodiversity safeguards, while policymakers do acknowledge biodiversity, to date forestry policies have tended to prioritize carbon and timber production, with biodiversity treated as a secondary co-benefit or a constraint to be mitigated, rather than a primary goal.

Conservation scientists (e.g. those cited in McAree, 2002; Guinness et al., 2020; Adenaeuer et al., 2021; Molloy et al., 2024) advocate for native woodland restoration and more biodiversity-focused forestry approaches. Their key concerns cover four areas: First, in terms of plantation monocultures, commercial Sitka spruce plantations, while effective for carbon and timber, provide limited habitat for native biodiversity compared to mixed-species or native forests. Second, relating to site selection are concerns about afforestation on ecologically sensitive sites (peatlands, species-rich grasslands, areas of high conservation value) and a call for rigorous environmental impact assessments to guide planting locations. However, under the current Irish afforestation programme, planting on such lands is not permitted, reflecting strengthened environmental safeguards and improved regulatory screening of planting locations. Third, regarding long-term management, scientists emphasize the importance of ongoing management interventions (e.g. thinning, deadwood retention, promoting natural regeneration) to enhance biodiversity in forests, as opposed to "plant-and-forget" approaches. And finally, they call for stronger monitoring of biodiversity conditions in grant-aided forests and stricter enforcement of existing environmental guidelines and safeguards.

Lapin et al. (2025) survey forest restoration practitioners across Europe, including Ireland. Practitioners report being motivated by goals of ecosystem restoration, climate mitigation, and knowledge acquisition. Irish practitioners in the survey highlight challenges such as limited funding, a lack of native tree seed sources, intense deer browsing pressure on young trees, and insufficient institutional support for restoration initiatives. They note the importance of collaborative networks, knowledge exchange platforms, and flexibility in management. Many practitioners express frustration with rigid policy frameworks that limit their ability to adapt practices to site-specific conditions and emerging challenges.

In sum, there are clear divergences in stakeholder perspectives. Farmers and landowners prioritize flexibility, cultural identity, and economic viability, and many remain wary of long-term land-use change. Local communities seek meaningful involvement and local benefits, fearing negative landscape and social impacts if forestry is imposed without their input. Policymakers focus on climate targets and economic balances, sometimes underestimating on-the-ground barriers. Conservation scientists prioritize ecological integrity and long-term sustainability, advocating approaches that may conflict with short-term economic goals. These tensions cannot be resolved by technical fixes or financial incentives alone. Effective forest carbon farming policy will require genuine multi-stakeholder dialogue, co-creation of context-appropriate solutions, and governance mechanisms that balance diverse values and objectives. The Living Lab paradigm—with its emphasis on participatory co-creation, social learning, and iterative adaptation—offers a promising framework for navigating these complex dynamics (Evans et al., 2016), though it has yet to be widely applied in the Irish forestry context.

*Native woodland restoration versus commercial forestry schemes*

A central strategic question in Irish forest carbon policy is how to balance native woodland restoration with conventional commercial forestry (primarily conifer plantations). The evidence base reveals significant differences in carbon, biodiversity, and social outcomes between these approaches.

Guinness et al. (2020) report that native woodlands in Ireland provide significant ecosystem service value (e.g. an estimated €35 million annually in amenity value), which reflects the high level of public appreciation for native forests. Under the Forestry Programme 2014–2020, broadleaf planting increased to 21% of new afforestation by 2017, and native or mixed-species forests now comprise about 32% of Ireland's forest estate. However, this is still far below the proportion of native woodlands in most European countries.

Native woodlands offer multiple benefits beyond carbon sequestration. For instance, in relation to biodiversity, native woodlands support much higher species richness and abundance of native flora and fauna compared to monoculture conifer plantations. They provide habitat for specialist woodland species, many of which are of conservation concern (McAree, 2002; Biber et al., 2020). In terms of ecosystem services, native forests also deliver superior benefits for water quality regulation, soil stabilization, and flood mitigation, and they offer recreational and cultural ecosystem services that plantations typically do not (Carlier et al., 2024). They align with and strengthen cultural values, too, as native woodlands are part of Ireland's natural heritage and are valued for their landscape aesthetics, cultural significance, and contributions to the local sense of place (Fléchard et al., 2007; Ó Foghlú, 2022). A fourth benefit relates to climate resilience: Diverse, mixed-species native forests are likely to be more resilient to climate change impacts, pests, and diseases than single-species plantations; they can adapt better to changing conditions and disturbances (Andersson et al., 2017; Lundholm et al., 2020).

Commercial conifer plantations in Ireland (dominated by non-native Sitka spruce, *Picea sitchensis*, and lodgepole pine, *Pinus contorta*) have been the primary focus of afforestation since the mid-20th century. These plantations offer certain advantages: For example, in terms of rapid carbon sequestration, fast-growing conifers accumulate biomass carbon quickly in the first few decades after planting, contributing to near-term climate mitigation (Duffy et al., 2020; Byrne et al., 2024). In relation to timber production, they supply economically valuable timber for construction, pulp, and bioenergy, thus forming the backbone of Ireland's forest industry and rural employment in forestry sectors. Another advantage pertains to landowner income: Shorter rotation cycles (35–45 years for Sitka spruce) mean that landowners can realize a financial return (timber harvest) within a lifetime, whereas native hardwoods like oak may take 80–120 years to mature.

However, commercial plantations also present challenges. First is the issue of limited biodiversity: Dense conifer monocultures with closed canopies and acidic leaf litter provide poor habitat for most native species. Biodiversity in such plantations is significantly lower than in native woodlands (McAree, 2002; Biber et al., 2020). The second challenge relates to the environmental impacts, as conifer plantations can acidify soils and watercourses, impacting aquatic ecosystems and sensitive habitats, especially when planted on peat or poorly buffered soils (Carlier et al., 2024). Third is the impact on the landscape, as large blocks of uniform Sitka spruce are often perceived as visually monotonous or even "alien" in the Irish landscape, which has a corresponding effect on public acceptance (Ní Dhubháin et al., 2009; Ó Foghlú, 2022). The final challenge involves carbon permanence: Short-rotation plantations that are clear-felled and replanted lead to periodic carbon stock fluctuations and emissions. The long-term net carbon benefit depends on the fate of harvested wood (e.g. how much ends up in long-lived products versus being immediately emitted).

In recognition of these issues, the Forest Service Biodiversity Plan (McAree, 2002) introduced requirements to enhance biodiversity within commercial forestry schemes. These included: that a minimum of 20% of the plantation area must consist of species other than Sitka spruce or lodgepole pine (to increase tree species diversity); that at least 10% of the area should be retained as open space (rides, glades, habitat corridors); that sensitive habitats should be protected (e.g. by not planting on intact peatlands and wetlands, by adding buffers for watercourses, and by preserving archaeological sites); and that native woodland edges and riparian buffers should be established around plantation blocks.

In a later study, Farrelly et al. (2022) review the implementation of these safeguards and find mixed results. Species diversity in new plantations has improved modestly, and more open space is being left unplanted, but systematic monitoring of biodiversity outcomes remains limited, and enforcement of conditions (e.g. maintaining buffer zones and planting required native percentages) has been inconsistent. However, recent policy developments indicate a strengthening of these requirements. The updated Forestry Standards Manual (2026) introduces stricter provisions for conifer afforestation, including a minimum of 20% broadleaf species and at least 15% of the area retained as open space and biodiversity habitats. Despite these improvements, the consensus remains that biodiversity in conifer plantations is substantially lower than in native woodlands.

Biber et al. (2020) quantitatively model the trade-offs between timber production, carbon sequestration, and biodiversity across different forest management strategies. One key insight from their analysis is that maximizing timber production through intensive, even-aged conifer plantations yields high short-term carbon sequestration but very low biodiversity outcomes. Another insight is that prioritizing biodiversity (e.g. via continuous-cover forestry, longer rotations, mixed native species) reduces timber yields and short-term carbon uptake but enhances long-term ecosystem resilience and multi-functionality. A third insight is that intermediate strategies (such as mixed-species plantations, or landscape mosaics that combine plantations with native woodland set-asides) can achieve more balanced outcomes across objectives, although these do still require careful spatial planning.

The modeling underscores that no single "optimal" strategy exists for all objectives; trade-offs are inevitable. Appropriate approaches depend on site conditions, landscape context, and societal priorities. However, current Irish forestry grant structures and guidelines still tend to favor conventional spruce plantations, offering limited flexibility and little incentive for landowners to pursue more biodiversity-friendly or mixed approaches.

Lapin et al. (2025) study the practical challenges involved in expanding native woodland restoration, which are different from those of commercial forestry. For instance, in relation to seed and planting stock, there is limited commercial availability of many native tree species, especially from local Irish provenances. Scaling up native woodland planting is thus constrained by seed supply and nursery capacity for species like oak, birch, rowan, and so on. Regarding establishment costs, native broadleaf trees often have higher planting and early maintenance costs and slower early growth, meaning that landowners may require longer premium payment periods or higher levels of support to make growing these economically viable. Another challenge relates to deer browsing: Large deer populations (e.g. Sika, fallow deer) in parts of Ireland are causing severe damage to young broadleaf plantings, meaning that native woodland projects must incorporate expensive fencing or culling programs. There is also the challenge of knowledge gaps, as less silvicultural knowledge and guidance is available for establishing and managing native woodlands compared to well-established conifer plantation practices. Many landowners and foresters lack experience with close-to-nature forestry techniques. Finally, market barriers present a challenge: the markets for native hardwood timber (e.g. oak, beech, alder) are currently less developed in Ireland than the markets for softwood. Thus, the long rotations and uncertain markets make native woodland a less straightforward financial proposition.

Despite these challenges, Lapin et al. (2025) find that practitioners remain strongly motivated to engage in native woodland restoration, driven by conservation values, ecosystem service benefits, and the recognition that diverse forests will be more climate-resilient in the long term.

Farmers have mixed opinions on whether they prefer native or commercial forestry. Duesberg et al. (2013) note that some farmers view native woodlands more favorably than conifer plantations due to their aesthetic and cultural value, while others prefer fast-growing conifers because the trees generate a quicker financial return and the farmers are more familiar with managing them. Irwin et al. (2022) report that many farmers are willing to plant small areas of native trees for amenity or environmental reasons; however, when it comes to larger-scale afforestation intended as a significant enterprise, they often lean toward commercial species to ensure economic returns.

The evidence points to a clear trade-off: commercial conifers excel in rapid carbon sequestration and timber production, whereas native woodlands excel in biodiversity conservation and long-term resilience. Achieving Ireland's biodiversity commitments alongside its climate targets will require a significant expansion of native woodland restoration, supported by enhanced financial incentives, technical advisory services, and market development for native hardwood products. At the same time, commercial forestry will continue to play a role in carbon and timber goals, but it must be practiced with strong biodiversity safeguards. The optimal path forward is likely a landscape-scale approach that integrates multiple forest types—strategically siting commercial plantations on lower biodiversity lands, prioritizing native woodland in ecologically sensitive or high-value areas, and including agroforestry and/or mixed systems where appropriate. Such a mosaic would provide connectivity for wildlife and a balance of ecosystem services (Biber et al., 2020; Carlier et al., 2024). This integrated approach, however, requires policy frameworks that are more flexible and spatially targeted than current schemes, as well as improved cross-sectoral planning.

*Afforestation processes and land availability in Ireland*

Despite having ambitious afforestation targets, Ireland has experienced declining tree planting rates in recent years. This raises questions about land availability, farmer willingness, and policy effectiveness in driving afforestation.

In their spatial assessment of land that is potentially available for afforestation in the Republic of Ireland, Farrelly et al. (2015) estimate that roughly 700,000 hectares of agricultural land could be suitable for afforestation without significantly impacting food production or violating environmental constraints. This is almost equivalent to the size of the existing forest estate (~770,000 ha). However, the authors stress that *potential* availability does not equal *actual* availability. A key constraint currently is farmer willingness: Even on marginal or low-productivity land, many farmers are reluctant to convert to forestry due to the cultural and personal factors discussed earlier (Duesberg et al., 2013). There is also the problem of land fragmentation. As Irish farms are typically small and segmented, this limits the scale of contiguous new forests and can reduce economies of scale for forestry operations. Further, on a regional variation level, the largest areas of plantable land are in the west and upland regions, which often have poorer access, harsher climates, and thus higher establishment challenges. A fourth constraint relates to there being competing uses—such as renewable energy (wind farms), peatland restoration, and agricultural expansion—for the same marginal land that is suitable for forestry.

According to analyses by Adenaeuer et al. (2021) and others, annual afforestation rates in Ireland have fallen from peaks of over 20,000 hectares in the 1990s to below 4000 hectares in recent years—which is well short of the Climate Action Plan's target of 8000 ha per year. It should be noted, however, that these historically high afforestation rates were often achieved on land types that would no longer be eligible under current environmental requirements, such as peatlands and High Nature Value grasslands. This decline has occurred despite increased grant rates and premium payments. Four key factors are thought to have contributed to the downturn. The first relates to agricultural profitability: The removal of EU milk quotas in 2015 sparked considerable dairy expansion, and strong livestock prices have raised the opportunity cost of land. Many farmers can earn more (or believe that they can) by keeping land for use in agriculture rather than planting it with trees. The second key factor is uncertainty surrounding policy: Because of frequent changes and delays in forestry schemes (e.g. periodic scheme suspensions, evolving environmental regulations), farmers are hesitant to commit to long-term land-use changes. In a similar vein, the third factor is licensing delays. Afforestation in Ireland requires detailed licensing processes to accommodate the necessary environmental and archaeological safeguards. In recent years, a backlog in the processing of planting licenses (due to environmental appeals and resource constraints in the Forest Service) has significantly slowed down approvals, frustrating landowners and investors alike. Finally, negative perceptions persist within some farming communities, which continue to view forestry as "land abandonment," contrary to the traditional vision of active farming. There is also concern that increased forestry in an area will reduce the social fabric of local farming communities (Duesberg et al., 2013; Ó Foghlú, 2022).

Matthews and O'Neill (2025) highlight fundamental tensions between Ireland's agricultural policy (e.g. targets for increased dairy and beef output under Food Wise 2025) and its afforestation targets. It is not possible to achieve both fully on a finite land base without major productivity gains or land-use change. The analysis suggests that, absent policy interventions, market forces will favor agriculture on most land, given current commodity prices and subsidy structures. Achieving climate goals will thus require policies that internalize the environmental costs of agriculture (methane, nitrous oxide emissions) and the benefits of forestry. In other words, explicit trade-off decisions and incentives are needed to reallocate land from pasture to trees in a climate-optimal way.

Bishop et al. (2024) similarly argue that clear national direction is needed on land-use allocation for net-zero targets. They advocate for spatial planning frameworks that earmark priority areas for afforestation, as opposed to using them for agriculture, conservation, peatland restoration, and so on, based on criteria like carbon sequestration potential, biodiversity value, and economic productivity. Without such integrated planning, sectoral policies will continue to conflict and undermine each other.

A notable issue in Ireland is the legacy of past afforestation on peat soils. Guinness et al. (2020) point out that planting trees on peatlands can be counterproductive for climate mitigation, as peat soils store large carbon stocks that can be released when drained or disturbed. Historically, a significant portion of Irish forestry (especially state-led planting in the mid-20th century) took place on peatland, particularly in the western counties. Current policy now prohibits afforestation on *intact* peatlands and instead promotes peatland rewetting and restoration for climate benefits. However, the legacy plantations on peat still pose challenges: they may be net carbon sources over their life cycle, and decisions are needed on whether to harvest and restore these sites or try to manage them as long-term forests.

Duffy et al. (2020) underscore the importance of site selection: their modeling shows that afforestation on mineral soils leads to clear net carbon uptake, whereas on organic peat soils it can lead to net emissions. This reinforces Ireland's move to steer planting toward mineral soils and away from peatlands, for climate reasons.

Given the resistance to full conversion of farmland to forestry, agroforestry (integrating trees into active farms) has been proposed as a win–win. Irwin et al. (2022) and Olave et al. (2025) both find among farmers interest in agroforestry systems (such as silvopasture, where trees and livestock coexist). Agroforestry could increase tree cover and carbon sequestration while allowing farmers to maintain an agricultural enterprise. However, adoption remains minimal. Noted barriers include limited policy support, as agroforestry schemes in Ireland have historically been pilot-scale and less financially attractive than full afforestation grants; lack of knowledge, as many farmers and advisers are unfamiliar with agroforestry design and management, and few local examples or technical guidance exist; and uncertainty more generally—because agroforestry is uncommon, its long-term profitability, its effects on livestock and crop yields, and its eventual timber value remain uncertain. Concerns around eligibility for agricultural subsidies have also been identified as a barrier; however, under the current programme, qualifying applicants may retain access to Basic Income Support for Sustainability (BISS) in addition to afforestation grants and premiums, potentially reducing this constraint.

Despite these barriers, surveys show that some farmers would consider agroforestry if there were clearer incentives, robust demonstrations of its benefits, and assurances that it would not jeopardize their farm payments. Developing robust agroforestry support programs, demonstration sites, and advisory services could help unlock this potential.

The synthesis indicates that Ireland's afforestation constraint is not primarily physical land scarcity. Farrelly et al. (2015) estimate that substantial agricultural land could be biophysically suitable for afforestation, while Adenaeuer et al. (2021) and related adoption studies show that actual uptake is constrained by farmer willingness, opportunity costs, policy complexity and perceived loss of land-use flexibility. This distinction is central to the policy–practice misalignment framework: land may be technically available, but not socially, economically or institutionally available under current conditions.

Agroforestry appears as a bridging pathway because it can increase tree cover without requiring full exit from farming. Its importance lies not only in potential carbon or biodiversity gains, but in its compatibility with farmer identity and land-use flexibility. However, the reviewed studies indicate that agroforestry remains limited by weak advisory capacity, uncertain long-term profitability and insufficient demonstration examples (Irwin et al., 2022; Olave et al., 2025).

## Discussion

### *From thematic review to diagnosis of policy–practice misalignment*

The main contribution of this review is to explain low afforestation and forest carbon farming uptake in Ireland as a policy–practice misalignment. The evidence does not suggest that Ireland lacks all technical pathways for forest-based carbon mitigation. Instead, the problem is that available pathways are not sufficiently aligned with landholder decision-making, biodiversity safeguards, scheme complexity, long-term economic uncertainty and local legitimacy.

This framework adds to existing adoption and governance literature by linking four domains that are often discussed separately: ecological pathway suitability, policy and scheme design, farmer adoption constraints and trusted delivery mechanisms. The diagnostic value of the framework is that it explains why technically sound or financially supported schemes may still fail: they can be misaligned with farming identity, land-use flexibility, administrative capacity, biodiversity legitimacy or trust in policy stability.

### *Why uptake remains low despite policy support*

A recurring pattern across the reviewed literature is that financial incentives alone are insufficient when tree planting is perceived as a long-term and partly irreversible shift away from farming. From a behavioural perspective, afforestation adoption is shaped by attitudes, social norms, perceived control, compatibility with farming identity and perceived complexity. This helps explain why grant and premium schemes may not overcome concerns about land-use lock-in, intergenerational flexibility, administrative burden and uncertain long-term returns. In this sense, low uptake is not simply a failure of communication, but a failure to design schemes around the decision logic of landholders.

### *Pathway choice as an adoption problem*

The reviewed evidence suggests that the ecological merits of a pathway and its adoption feasibility are inseparable. Native woodland restoration may provide stronger biodiversity and climate-adaptation benefits, but it may not always align with landholder objectives or short-term economic expectations. Commercial forestry can generate timber and relatively rapid biomass accumulation, but can face legitimacy concerns where biodiversity, landscape or community impacts are contested. Agroforestry occupies an intermediate position because it can add trees while retaining agricultural production, but it remains under-supported in advisory and policy systems. Forest carbon farming in Ireland therefore requires pathway portfolios rather than a single afforestation model.

### *Participatory approaches as implementation mechanisms*

Living Labs and Participatory Action Research should be understood as implementation mechanisms rather than generic recommendations. Their potential value lies in testing whether proposed forestry models are workable for farmers, communities, advisers and policymakers before they are scaled. In the Irish context, participatory approaches could support co-design of scheme rules, locally appropriate biodiversity safeguards, trusted advisory networks, peer learning and monitoring arrangements. However, the review also shows that such approaches are not yet strongly documented in Irish forestry practice. This is a critical research and implementation gap.

### *Integration of carbon, biodiversity, and climate adaptation goals*

A central challenge highlighted by this review is the difficulty of simultaneously optimizing carbon sequestration, biodiversity conservation, and climate adaptation within forestry projects. While earlier analyses suggest that policy frameworks have tended to prioritize carbon (and related timber production), with biodiversity and adaptation often treated as secondary co-benefits or constraints (McAree, 2002; Guinness et al., 2020), recent policy developments reflect a more integrated approach. For example, the Forest Strategy 2023–2030 sets out an overarching objective to expand the national forest estate in a manner that delivers multiple benefits, including climate mitigation, biodiversity enhancement, water quality protection, wood production, economic development, and quality of life.

Fortunately, the evidence does identify four contexts in which carbon, biodiversity, and adaptation goals can align. The first of these synergies involves **establishing native woodlands on degraded or marginal agricultural lands** (or on cutaway peatlands), to sequester carbon, create biodiverse habitats, and enhance landscape resilience (Molloy et al., 2024; Lapin et al., 2025). This is a clear nature-based solution synergy. The second relates to **mixed-species forestry**, whereby diversified forest stands (mixing native and exotic species, or conifers with broadleaves) can achieve reasonable carbon accumulation while providing better biodiversity habitat and greater resilience to pests and storms than monocultures (Biber et al., 2020; Lundholm et al., 2020). The third synergy has to do with **agroforestry systems**: Integrating trees into farmland (silvopasture, shelterbelts, riparian buffers) can sequester carbon and enhance on-farm biodiversity (like birds and pollinators), improve the microclimate for livestock/crops, and enable maintaining agricultural production (Lojka and Hoffmannová, 2024; Olave et al., 2025). The fourth synergy, **riparian woodland buffers**, involves planting native trees along rivers and streams to sequester carbon and provide biodiversity benefits (habitat connectivity, water quality improvement), while also reducing flood risks and stabilizing banks (Carlier et al., 2024). This supports both adaptation (flood mitigation) and biodiversity. This approach is also reflected in recent policy instruments, such as the Native Tree Area Scheme (NTA 2), which specifically supports the establishment of native forests for water protection.

Conversely, however, there are three inherent trade-offs where objectives conflict. First, in relation to **short-rotation plantations**, maximizing short-term carbon uptake via fast-growing conifer monocultures often sacrifices biodiversity and may reduce long-term resilience (as these stands are more vulnerable to disease or windthrow) (Biber et al., 2020). Second, **afforestation of species-rich grasslands** (i.e., planting forests on high-biodiversity open habitats such as species-rich calcareous grasslands or heaths) can reduce overall landscape biodiversity even if carbon storage increases (Guinness et al., 2020). However, the Forest Programme 2023–2027 explicitly considers High Nature Value (HNV) farmland, requiring ecological assessment of applications in such areas to safeguard existing ecological value and avoid inappropriate afforestation. Care is needed to avoid such maladaptive practices. Finally, in relation to **intensive management**, forestry practices that maximize timber yield (short rotations, clear-felling, intensive thinning) can diminish structural diversity and deadwood, thereby limiting habitat complexity and reducing biodiversity (McAree, 2002). Similarly, some adaptation measures (like heavy thinning to reduce storm risk) might lower short-term carbon stocks.

Several studies advocate for integrated, landscape-scale approaches to optimize multiple objectives (Biber et al., 2020; Bishop et al., 2024; Carlier et al., 2024). Such approaches would involve: strategically targeting **commercial plantations** to sites with high timber productivity potential but lower biodiversity value, where fast carbon gains can be made with minimal ecological sacrifice; prioritizing **native woodland restoration** on sites with high biodiversity importance or cultural significance (even if carbon uptake is slower there), to maximize co-benefits; establishing **agroforestry systems** on productive farmland where maintaining agriculture is important, thereby integrating trees without wholly displacing farming; and creating **mosaic landscapes** where patches of plantation, native woodland, agroforestry, and other land uses form a heterogeneous landscape that provides connectivity for wildlife and a balance of services.

Implementing such integrated landscape approaches would require institutional innovations. Cross-sector coordination mechanisms (among agriculture, forestry, and environment agencies), spatial planning tools, and participatory governance processes are needed so that stakeholders can collaboratively decide the right land use in the right place (Best et al., 2022; Carlier et al., 2024). The Living Lab model could facilitate this by bringing stakeholders together for joint planning and scenario modeling of landscape futures, fostering shared learning and negotiated solutions.

*Living Labs as implementation testbeds, not proven solutions*

The review does not show that Living Labs are already an established mechanism in Irish forestry. Rather, it shows that the kinds of problems identified in the literature—low trust, limited co-design, weak monitoring of outcomes, and poor alignment between scheme rules and farmer realities—are the types of problems for which participatory testing may be useful.

Living Labs and Participatory Action Research should therefore be understood as implementation testbeds. Their potential role would be to test whether proposed forestry pathways, carbon indicators, biodiversity safeguards, payment rules and monitoring requirements are understandable and acceptable to landholders and other stakeholders before they are scaled. This is a practical research and policy hypothesis emerging from the review, not an empirical conclusion that Living Labs have already solved Irish afforestation barriers.

*Policy–Practice gaps and implementation challenges*

One of the most striking findings is the persistent gap between Ireland's forestry policy ambitions and the actual on-the-ground outcomes. Despite strong high-level commitments (e.g. national climate targets, biodiversity strategies) and substantial funding, tree planting rates remain far below goals (Farrelly et al., 2015; Adenaeuer et al., 2021, 2022). This indicates that a number of barriers along the implementation chain are preventing policy from translating into practice.

For instance, Ireland's forestry grant schemes provide significant incentives (establishment grants and 15-year annual premiums), but they may still be insufficient relative to the opportunity costs of farming, especially in regions of intensive agriculture (Irwin et al., 2022). For dairy farmers in particular, the income from continued milk production can far outweigh forestry premiums. Moreover, while premium payments are stable for their defined duration, farmers remain concerned about longer-term financial risks beyond this period, including uncertainty regarding future timber revenues, market conditions, and broader policy developments affecting the forestry sector (Duesberg et al., 2013; Knapp, Byrne et al., 2024, 2024).

Deep-rooted cultural factors also play a major role. The farming identity is so strongly tied to active agriculture that the decision to plant trees is often seen as giving up farming (Duesberg et al., 2013). In some local contexts, there is stigma attached to those who "sell the land to trees," as if it were an abandonment of community values. This social dimension means that, no matter how attractive grants are, some farmers will not consider forestry unless their perceptions change. Gaining social acceptance ("social license") for afforestation in farming communities is therefore one of the key challenges (Ó Foghlú, 2022), which may involve public engagement, peer influence (e.g. respected farmers adopting trees), and reframing forestry as compatible with farming (e.g. via agroforestry or part-farm afforestation models).

The process of planting trees in Ireland has historically been administratively cumbersome. Obtaining an afforestation license involved environmental screening (e.g., Appropriate Assessment for Natura sites) and public consultation, which, while essential, previously led to delays due to resource constraints and procedural bottlenecks. Adenaeuer et al. (2021) note that these complexities deterred applicants. However, recent reforms have cleared the licensing backlog, and the process is now more streamlined and efficient, improving timelines and predictability for applicants.There is also only limited technical support available for farmers—while Teagasc has an advisory service, historically it has had far fewer forestry advisers than agricultural ones, leaving many farmers without guidance on forestry options (Olave et al., 2025).

Many farmers are simply not familiar with forestry; they do not know what different schemes entail, what managing a forest involves over time, or what the potential benefits and risks are. Irwin et al. (2022) find lack of knowledge to be a key factor in farmers' reluctance to try agroforestry. Traditional agricultural extension services have not strongly promoted forestry, and independent information can be hard to come by. There are relatively few demonstration farms that showcase successful integration of forestry, and few formal farmer-to-farmer learning opportunities around tree planting. This knowledge gap is breeding uncertainty and caution.

On a policy level, Ireland's agricultural and environmental policies sometimes send mixed signals. For instance, subsidies under the Common Agricultural Policy (CAP) have historically rewarded keeping land in agriculture (through area-based payments and stocking density incentives), while forestry grants encourage taking land out of agriculture. Matthews and O'Neill (2025) argue that unless these incentives are aligned, many farmers will logically choose to continue farming. Additionally, high-level strategies like Food Wise 2025, which promotes output growth, and Climate Action Plan, which promotes afforestation, need to be reconciled. There is also a lack of integrated land-use policy to handle these trade-offs (Bishop et al., 2024)—currently, each sector is planned separately.

As noted earlier, existing policies do include biodiversity and environmental conditions, but weak monitoring and enforcement regimes mean that these may not always be implemented. Guinness et al. (2020) and Farrelly et al. (2022) highlight that outcomes (biodiversity, community impact) are not well tracked, so problems can persist unseen. Without transparent reporting on how schemes are performing (e.g. how many trees survive, what biodiversity outcomes are achieved, what local feedback is), it is hard to learn and adjust. Lack of accountability mechanisms can also reduce trust—for example, communities might grow to distrust promises of "biodiversity-friendly forestry" if they see plantations that fail to meet the requisite standards and yet suffer no consequences.

Closing these gaps will require multifaceted changes along the lines of these:

- **Better financial alignment:** Enhancing and refining financial incentives to better reflect opportunity costs and long-term risk could make forestry more competitive compared with agriculture. While the current Forestry Programme already provides higher grants and premiums for native woodland, and recent updates (e.g. mid-term review) have increased payments for agroforestry, further efforts may be needed to ensure that incentives adequately address long-term income security and perceived risks among landowners. Schemes may also benefit from mechanisms that extend income streams beyond the premium period or provide guarantees/insurance for long-term returns (Knapp, Byrne et al., 2024, 2024).
- **Streamlined administration:** Simplifying the application process, maintaining efficient licensing timelines, and providing a single point of contact for applicants can reduce transaction costs (Adenaeuer et al. 2021). Recent reforms have addressed the forestry licensing backlog, with current turnaround times reported to be under six months, representing a significant improvement in system performance. Continued efforts are needed to sustain this efficiency, alongside further digitalization of application and mapping processes and the provision of clear guidance to applicants.

- **Flexible, diversified schemes:** Offering a menu of planting options, rather than only a full afforestation model, can enable farmers to choose smaller-scale planting approaches such as riparian buffers, shelterbelts, and agroforestry, with proportionate support. Recent developments, including the Native Tree Area Scheme, provide attractive financial incentives for small-scale native planting, representing important progress toward greater flexibility. Further expansion and uptake of such options could help accommodate diverse farm goals and increase participation (Irwin et al., 2022; Olave et al., 2025).
- **Knowledge transfer:** Investing in robust outreach—setting up demonstration forests in every region, running field days for farmers to visit successful forestry projects, facilitating "farmer forest" discussion groups, and integrating forestry into agricultural education, including having respected local farmers who have planted trees share their experiences—could be highly persuasive (Lapin et al., 2025).
- **Social license and engagement:** Involving community leaders and farm organizations in designing forestry programs and establishing forums in which local concerns about forestry can be aired and addressed would help to secure local buy-in. Ensuring that communities see the benefits (like jobs and recreational access) accruing from the new forests would also help to build support (Evans et al., 2016; Ó Foghlú, 2022).
- **Policy integration:** Developing an integrated land-use strategy with spatial planning that reconciles agriculture and forestry targets is crucial (Bishop et al., 2024; Carlier et al., 2024). For example, it would need to identify priority afforestation zones where incentives are increased and agricultural expansion is curtailed, and conversely zones where prime agricultural land is preserved.
- **Robust monitoring and adaptive management:** Establishing and further strengthening processes for long-term monitoring of afforestation outcomes (carbon, biodiversity, and socioeconomic impacts) would support more comprehensive evaluation of forestry policy effectiveness. Existing reporting mechanisms, such as the Annual Forest Statistics, already provide valuable data on afforestation rates, carbon, and economic contributions. However, expanding these systems to include more detailed biodiversity indicators, social outcomes, and qualitative feedback from participants could enhance adaptive management by enabling better understanding of scheme performance and informing policy adjustments (Farrelly et al., 2022).

By addressing these implementation barriers in a coordinated way, Ireland could improve the translation of its well-intentioned policies into tangible progress on the ground.

*Limitations of the evidence base*

It is important to acknowledge the limitations in the evidence base itself, as these constrain the confidence and generalizability of our conclusions and point to areas for further study:

While this review covers both the Republic of Ireland and Northern Ireland, the bulk of the studies included here address the Republic. Only two of the included studies focus specifically on Northern Ireland (Ní Dhubháin et al., 2009; Olave et al., 2025). All-island comparative perspectives are rare. This is a gap since policies and contexts differ between the Republic and Northern Ireland; opportunities for cross-jurisdictional learning (North–South) are not well explored.

The evidence is weighted toward recent years (2020–2025). Few long-term or historical studies track how outcomes unfold over the decades that forestry requires. There is limited longitudinal data on, for example, how biodiversity in new woodlands changes from planting through maturity, or how farmer attitudes might shift over time. Many studies provide a snapshot rather than a long-term picture. The timescales of climate and forestry (multi-decade) demand research that can capture trends over 20 years and longer, which is currently scarce (Farrelly et al., 2022).

We found a predominance of policy analysis, modeling, and survey research. There are relatively fewer field-based ecological studies directly measuring biodiversity or carbon in Irish forest projects. Experimental studies (e.g. trials comparing different forestry practices) are also limited. Qualitative in-depth case studies on social processes are few. Notably, participatory action research—where researchers and stakeholders co-create knowledge—is almost absent in this domain (Evans et al., 2016 is one example, but it is not Ireland-specific). The lack of participatory research means that the literature might miss practical insights that could be gained by directly involving stakeholders in the research process.

Many studies, especially policy and modeling ones, infer outcomes (like carbon sequestering or biodiversity impact) through models or proxies rather than measuring them on the ground. Quantitative data on biodiversity outcomes in Irish forestry are surprisingly sparse; for instance, few studies count species or monitor habitat changes in new forests. Carbon estimates often rely on general models rather than site-specific data, which could introduce error if local conditions differ from assumptions. Climate adaptation outcomes (like increased flood resilience or microclimate buffering) are seldom quantified. Social outcomes such as community well-being and equity implications are almost entirely absent from the evaluated literature (Guinness et al., 2020; Farrelly et al., 2022). This suggests that our understanding of the full suite of impacts (positive and negative) from forest carbon projects in Ireland is incomplete.

While there is substantial research on farmers, other voices get less attention. Local community members (non-farmer residents) appear in only a handful of studies (Fléchard et al., 2006, 2007). We found no studies incorporating Indigenous knowledge (not a major factor in Ireland) or perspectives of youth or new entrants to farming. Policymakers and forestry industry professionals are usually analyzed through document analysis, not direct interviews. Thus, the literature may not fully capture the views of all relevant stakeholders; some perspectives could be underrepresented.

Few studies take an integrative approach that enables evaluating multiple objectives together. Most focus on carbon or biodiversity or social issues in isolation. Only a few (like Biber et al., 2020; Lundholm et al., 2020; Carlier et al., 2024) explicitly analyze synergies and trade-offs between objectives. This is a limitation because it is precisely those trade-offs that pose the real-world policy dilemmas that are at the heart of the issues. A more holistic analytical framework is needed in future research to support truly integrated policymaking.

Much of the literature diagnoses problems (barriers, gaps) but does not deeply analyze *how* successful implementation could be achieved. We have limited evaluative research on specific policy tools and pilot projects (e.g. how exactly a certain program failed or succeeded, and why). Best et al. (2022) is noted as a rare example that analyzes implementation impasses. There is thus a need for more "process evaluations" of interventions—studying initiatives in action to glean lessons about what works or does not work in practice.

These evidence gaps suggest priorities for future research (as elaborated in the "Recommendations for Future Research" section). In particular, there is a need for long-term monitoring studies, on-the-ground ecological measurements, more inclusive stakeholder research, integrated assessment of multi-objective outcomes, and practical implementation studies including innovation strategy, delivery, and acceleration mechanisms. Addressing these will require sustained investment and interdisciplinary collaboration, bringing together ecological, social, and policy researchers, ideally in partnership with practitioners.

*Relevance beyond Ireland*

The Irish case is not unique, but it is a clear example of a low-forest agricultural adoption system. Similar adoption problems can arise where tree planting competes with productive agriculture, where forestry is socially contested, and where landholders perceive afforestation as reducing autonomy or future flexibility. Evidence from broader European forest and land-use literature suggests that successful implementation requires not only technically credible carbon accounting, but also low-friction delivery, trusted advisory systems, and pathways that match local land-use identity. Thus, Ireland provides a transferable lesson: carbon farming instruments designed for ecological or accounting integrity may still fail if they are not designed for adoption.

The review has three limitations. First, the evidence base is relatively small and heterogeneous, combining peer-reviewed studies, policy reports, modelling papers and conceptual sources. The findings should therefore be interpreted as a diagnostic scoping synthesis rather than a quantitative evidence assessment. Second, Living Lab evidence in Irish forestry is limited; the review identifies Living Labs as a potential implementation mechanism, not as an empirically proven solution. Third, the Irish case is context-specific, but it is analytically relevant to other low-forest agricultural systems where carbon farming depends on landholder adoption, policy legitimacy and trust in delivery mechanisms.

## Conclusions

This scoping review shows that forest carbon farming in Ireland is constrained less by the absence of technical pathways than by policy–practice misalignment. Ireland has potential pathways for carbon sequestration, biodiversity recovery and climate adaptation through native woodland restoration, agroforestry and carefully designed afforestation. However, the uptake of these pathways remains limited because policy incentives, administrative processes, farmer decision-making and local legitimacy are not sufficiently aligned.

The evidence indicates that farmer adoption is shaped by more than payment levels. Land-use flexibility, farming identity, intergenerational concerns, administrative complexity, advisory support and trust in policy stability all influence whether forestry is perceived as a viable option. This explains why afforestation targets may remain unmet even when policy frameworks and financial incentives are in place.

The review therefore reframes Living Labs and Participatory Action Research as potential implementation mechanisms, not simply as engagement add-ons. Their value lies in testing forestry pathways with stakeholders, co-designing workable scheme rules, and building legitimacy through demonstration, monitoring and iterative learning.

For Ireland and comparable low-forest agricultural systems, the key challenge is to design forest carbon farming as an adoption-sensitive and biodiversity-compatible land-use transition. Future research should move beyond documenting barriers toward testing which combinations of incentives, advisory support, spatial targeting and participatory delivery can make carbon-oriented forestry both environmentally credible and practically acceptable.

### *Recommendations for future research*

Future research should focus on testing the policy–practice misalignment framework empirically. The first priority is to identify which misalignments are most binding in different Irish contexts: financial opportunity cost, permanence concerns, administrative burden, farming identity, biodiversity legitimacy or lack of trusted advice. This would require comparative case studies of farmers who adopt, reject or modify forestry options.

Second, research should test which combinations of incentives and pathway types are most acceptable to landholders. For example, agroforestry, native woodland, riparian planting and mixed systems should be evaluated not only for carbon and biodiversity outcomes, but also for perceived flexibility, compatibility with farming systems and long-term economic risk.

Third, monitoring research should connect carbon, biodiversity and social outcomes. The review shows that these dimensions are often studied separately. Future studies should develop indicators that can jointly assess carbon sequestration, biodiversity value, tree survival, farmer experience and community acceptance.

Fourth, Living Lab and Participatory Action Research pilots should be evaluated as implementation experiments. Research should examine whether co-designed schemes reduce transaction costs, increase trust, improve understanding of carbon/biodiversity indicators and lead to more acceptable forestry models.

Finally, future work should compare Ireland with other low-forest agricultural systems where tree planting competes with productive agriculture. This would help test whether the policy–practice misalignment framework is transferable beyond Ireland.

### *Recommendations for policy and practice*

The policy implications of the review follow directly from the policy–practice misalignment framework. The key task is not only to increase planting targets or payment levels, but to align forestry pathways with farmer decision-making, biodiversity legitimacy, administrative feasibility and trusted evidence.

First, Ireland should prioritize pathway portfolios rather than a single afforestation model. Native woodland, agroforestry, mixed systems, small-scale planting and commercial forestry with strong safeguards serve different purposes and appeal to different landholder motivations. Policy instruments should therefore support a menu of pathways that vary in scale, permanence, production orientation and biodiversity value.

Second, incentive design should address flexibility and perceived risk. Grants and premiums are necessary but insufficient if landholders fear long-term lock-in, loss of agricultural identity or uncertain future land value. Scheme design should therefore emphasize clarity, predictable payments, low transaction costs and options compatible with active farming, especially agroforestry and smaller-scale tree-cover measures.

Third, biodiversity and carbon outcomes should be monitored transparently. Forest carbon farming will not gain legitimacy if carbon claims are disconnected from biodiversity, soil, water and community impacts. Monitoring systems should make outcomes visible and understandable, including tree survival, species composition, habitat quality, carbon stock change and local feedback.

Fourth, advisory and peer-learning systems should be strengthened. The review shows that lack of knowledge, limited trusted advice and few visible demonstration examples constrain adoption. Forestry advice should be better integrated with agricultural advisory systems, and farmer-to-farmer learning should be supported through demonstration farms and locally credible examples.

Fifth, Living Lab-style pilots should be used selectively to test misalignment points before scaling. Such pilots should not be framed as generic participation exercises, but as structured experiments to test whether specific scheme rules, indicators, monitoring requirements and land-use models are workable for farmers, communities, advisers and policymakers.

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## CRediT authorship contribution statement

**Evgeny Lopatin:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Writing – original draft. **Mark Robins:** Conceptualization, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing.

## Declaration of competing interest

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

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## Data availability

No data was used for the research described in the article.

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