

RESEARCH ARTICLE

Interdisciplinary and Transdisciplinary Research to Improve Treescapes for the Benefit of People and Nature

Some love them, others hate them: Understanding farmers' tree planting decisions in Scotland

Albert Mvula  | Katrin Prager | Josie Geris

School of Geosciences, Department of Geography and Environment, University of Aberdeen, Aberdeen, UK

Correspondence

Katrin Prager

Email: katrin.prager@abdn.ac.uk

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Abstract

1. Agroforestry is increasingly recognized as a sustainable agricultural land use system with potential to sequester carbon, create and repair habitats, enhance biodiversity and offer environmental and socio-economic benefits, including improved agricultural productivity.
2. Agroforestry has the potential to significantly contribute to Scotland's plans to halt biodiversity loss by 2030 and achieve net zero greenhouse gas (GHG) emissions by 2045. However, as in many temperate countries, agroforestry adoption in Scotland remains low and poorly understood, hindering its expansion.
3. To understand and address barriers to agroforestry in Scotland, we conducted 31 interviews with farmers and crofters. This included 21 agroforestry adopters and 10 non-adopters. Four were classified as crofts, 27 were classified as farms and 5 of these farms were tenanted.
4. Our analysis revealed that an individual's perception of the impact of trees on their farm, their control over and preferences for the tree planting process, including species selection, is a key barrier to agroforestry adoption. Other factors included the availability of financial support, the future economic outlook for their farm enterprises if they choose agroforestry, challenges related to the existing Forestry Grant Scheme, land tenancy conditions that disadvantage tenant farmers and the availability of agroforestry knowledge.
5. We distilled seven distinct responses exhibited by farmers based on the interplay of their attitudes, perceived agroforestry norms, confidence, level of control over tree planting and subsequent maintenance activities.
6. To enhance the adoption of agroforestry in Scotland, it is therefore essential to implement targeted interventions and support mechanisms. These could include establishing a favourable policy environment for tenant farmers, enhancing and making agroforestry incentives more appealing, understanding and leveraging farmers' tree planting preferences and ensuring that agroforestry information is readily accessible to those new to the practice.

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KEYWORDS

agroforestry, barriers, behavioural control, climate change adaptation, on-farm tree planting, resilience, tree planting perceptions

1 | INTRODUCTION

1.1 | Background

Balancing food security with biodiversity, climate change mitigation and adaptation requires transformative measures in our food production systems to meet global socio-economic and environmental needs. Globally, agriculture is a significant contributor to greenhouse gas emissions, with current estimates indicating that 12%–21% of methane, carbon dioxide and nitrous oxide emissions originate from agricultural lands (Mukherji et al., 2024). In the United Kingdom, agriculture accounts for approximately 12% of total GHG emissions (DESNZ, 2022). Therefore, promoting sustainable agricultural systems is essential to ensure sustainable food production while maintaining the environmental sustainability of farmed landscapes.

Agroforestry, defined as the deliberate integration of woody vegetation with crops and/or livestock farming, has been shown to offer multifaceted benefits globally (Castle et al., 2021; McAdam et al., 2009; Smith et al., 2013; Waldron et al., 2017). With over 80% of Scotland's total land mass dedicated to agriculture (<https://www.gov.scot/publications/results-scottish-agricultural-census-june-2021/pages/1/ResultsfromtheScottishAgriculturalCensus:June2021-gov.scot>), agroforestry provides significant potential to contribute to Scotland's goal of achieving net-zero greenhouse gas emissions by 2045, as outlined in the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019. Understanding the barriers, opportunities and incentives that influence the adoption of agroforestry is therefore crucial for enhancing agricultural resilience and addressing climate change mitigation and adaptation in Scotland. This paper employs the Theory of Planned Behaviour to deepen our understanding of the factors that shape and influence farmers' tree planting decisions amidst various agroforestry barriers and opportunities. Initially, we investigate the current barriers and opportunities in agroforestry. Subsequently, we analyse how these factors impact tree planting decisions among farmers with diverse perceptions and experiences. Our goal is to leverage these new insights to enhance existing agroforestry opportunities while mitigating barriers, thereby contributing to greater adoption and expansion of agroforestry practices in Scotland.

In Scotland, agroforestry is actively promoted through government grant schemes that provide financial incentives for farmers to adopt the practice. However, our interviews with farmers and crofters revealed that the term 'agroforestry' is not widely recognized and often leads to confusion, thereby diminishing interest—even in cases where specific forms of agroforestry are already in use. Consequently, our discussions with farmers and crofters primarily

centred on tree planting in general, which encompasses all agroforestry systems, including hedgerows.

The ambiguity surrounding the definition of agroforestry in Scotland extends beyond individual farms. Within government-funded grant schemes, woodland creation—typically not classified as agroforestry—is incorporated under the agroforestry framework, further complicating distinctions between agroforestry and other forms of tree planting. While the presentation of our findings and subsequent discussion focuses broadly on tree planting, we retain the term 'agroforestry' in this paper to ensure its continued alignment with mainstream agroforestry research in Scotland and internationally.

1.2 | Impacts of agroforestry

An expanding body of literature continues to highlight agroforestry as a viable ecological strategy with substantial potential for environmental conservation and the restoration of degraded farmlands, while simultaneously enhancing socio-economic benefits for sustainable food production (Leduc & Hansson, 2024; Waldron et al., 2017). For example, studies by McAdam et al. (2009) and Smith et al. (2013) indicate that agroforestry contributes to a range of ecosystem services, including soil erosion control, carbon sequestration, pollination, pest regulation and nutrient retention, thereby benefiting both agricultural landscapes and surrounding communities. Furthermore, agroforestry systems have been recognized for their role in enhancing recreational opportunities, preserving cultural heritage and improving agricultural productivity (McAdam et al., 2009).

A global review analysing over 70 articles on agroforestry and its influence on pollination concluded that agroforestry practices promote or maintain pollination functions (Centeno-Alvarado et al., 2023). Additional research by Pretty (2018), Miller et al. (2020) and others corroborates agroforestry's positive effects on ecosystem services and biodiversity. A cumulative meta-analysis conducted in Europe found that silvoarable systems increased biodiversity by nearly 60% compared to conventional cropland, with notable expansions in bird and arthropod populations. Conversely, other agroforestry systems did not exhibit substantial biodiversity improvements (Mupepele et al., 2021).

Although research on the impacts of agroforestry in temperate and high-income countries remains limited, these systems are widely advocated for their extensive ecological and agricultural benefits, including improved nutrient and water cycling, enhanced agricultural productivity, carbon sequestration, flood mitigation and soil fertility restoration (Blaser et al., 2018; Brown et al., 2018; Newman et al., 2018; Pardon et al., 2018; Raskin & Osborn, 2019;

Rosenstock et al., 2019). In recognition of agroforestry's significance, the European Union's Common Agricultural Policy (CAP) has progressively increased financial support and incentives to promote agroforestry adoption, including direct payment schemes (Laporta et al., 2021; Porras et al., 2020).

While evidence of the impacts of various agroforestry systems in temperate countries remains scarce, decades of research in the tropics provide evidence of the multifaceted benefits on the environment, agricultural productivity, and human well-being. In a study to compare the performance of silvopastoral systems with other farm diversification strategies in Panama, Paul et al. (2017) found a 21% increase in economic returns for farmers who adopted silvoarable systems compared to non-adopters. The interaction between crops and trees has been shown to enhance crop productivity by optimizing nutrient recycling, reducing soil fertility loss through erosion and improving microclimatic conditions and soil ecosystems at the farm scale (Castle et al., 2021; Keesman et al., 2011; Luedeling et al., 2016; Paul et al., 2017). Based on the findings of Torralba et al. (2016) and Lovell et al. (2017), agroforestry systems offer windbreaks and protection for livestock against severe weather conditions, while also providing shade during hot summers.

1.3 | Adoption of agroforestry in the United Kingdom

Despite these benefits, the adoption of agroforestry in the United Kingdom remains low and poorly understood, with limited land coverage (Felton et al., 2023; Perks et al., 2018). According to den Herder et al.'s (2017) estimates, agroforestry in the United Kingdom only covers about 3.3% of the total agricultural land (about 551,000 ha), with the majority of this classified as livestock agroforestry (silvopastoral systems). The limited available literature on agroforestry in Scotland has highlighted several factors that hinder its adoption. Broadly, the structural divisions between forestry and agriculture in academia and policy, as well as negative perceptions regarding agroforestry among farmers, have been identified as significant barriers to on-farm tree integration (Glover et al., 2013; Graves et al., 2017).

The demand for increasing food production and maximizing the efficiency of production systems led to widespread removal of hedgerows and in-field trees on most UK farms between the 1940s and 1990s (Dover, 2019; Tilzey, 2021). While many Scottish farms already have trees, hedgerows and other woody vegetation, the perception that agriculture and forestry are separate economic activities that cannot be combined on the same parcel of land remains a barrier. Due to the long-standing cultural divide between agriculture and forestry, farmers often misunderstand agroforestry, perceiving it as a practice that would take land out of agricultural production (Soil Association Scotland, 2020). Additional barriers come from the productivist mindset of farmers who see their main purpose as food production (Hopkins et al., 2017), to whom trees on valuable

farmland are conflicting with their identity as 'good farmers' and food producers (Burton et al., 2020; Warren et al., 2016).

In addition to perceptions, knowledge gaps regarding agroforestry have been identified as significant barriers to its adoption. The lack of understanding of both the economic and ecological impacts on farm enterprises and resilience has hindered widespread adoption of agroforestry (Felton et al., 2023; Soil Association Scotland, 2020; Staddon et al., 2021). In their study of the barriers to the development of temperate agroforestry, Louah et al. (2017) found that most barriers to agroforestry adoption are related to insufficient knowledge of the ecological impacts of integrating trees with agriculture. Tosh (2021) and Felton et al. (2023) argue that the lack of expert knowledge on how to design and plant trees on farmland also makes tree planting challenging for new adopters of agroforestry.

Investigations by Dunn et al. (2020) and Felton et al. (2023) highlight several barriers to agroforestry in Scotland and England, including high deer populations, low financial returns, and conflicting climate change and food security policies. Under the current Agricultural Holdings (Scotland) Act 2003, tenant farmers must obtain written consent from landowners before engaging in agroforestry, which restricts their ability to plant trees on tenanted land. Despite the availability of grant schemes such as the Forestry Grant Scheme (FGS) and other financial assistance, literature indicates that challenges associated with the FGS—such as complex application processes, prescriptive grant conditions and low payment rates—have discouraged farmers from integrating trees into their farms (Soil Association Scotland, 2020; Tosh, 2021).

The 2024 updates to agroforestry options under the FGS have introduced several key changes. Planting density restrictions have been revised from a minimum of 200 trees per hectare to a flexible range of 150–200 trees per ha (Scottish Government, 2024). Additionally, the selection of tree species has been categorized into three groups: (1) broadleaves suitable for timber production, (2) broadleaves aimed at enhancing ecological diversity and (3) fruit and nut trees for business diversification. Grant payment rates have also been increased, with the previous rate of £3,600 per ha for a density of 400 trees per hectare now raised to £5,400. For planting densities of 150–200 trees per ha, the rates have been adjusted from £1,860 to £2,790 per ha. It remains to be seen whether these changes will sufficiently incentivize farmers to apply for the FGS and alter their tree planting practices.

Although agroforestry adoption has been widely researched on a global scale, literature specifically focused on Scotland remains scarce, with much of the existing scholarship centred on England and other temperate countries. This study provides a valuable contribution to understanding the factors influencing agroforestry adoption—or the lack thereof—among a diverse array of Scottish farmers. By encompassing both highly commercialized large-scale enterprises and traditionally small crofts, the research captures a broad spectrum of perspectives, offering nuanced insights into the challenges and motivations shaping agroforestry practices in Scotland.

Furthermore, this study examines the distinct challenges encountered by tenant farmers attempting to engage in agroforestry,

reinforcing its significance for policymakers in Scotland. In addition to identifying key obstacles to expanding tree planting, this paper investigates how various farmers perceive, navigate and respond to the barriers and opportunities associated with tree planting. By analysing these dynamics, the study provides insights into the factors that shape farmers' decision-making processes regarding agroforestry adoption.

1.4 | Theoretical framework

We adapted the Theory of Planned Behaviour (TPB) to guide the data analysis process and interpret the results for this paper. Developed by Ajzen (1985), the TPB posits that an individual's intention to engage in a certain behaviour can predict whether they will actualize that behaviour. According to the theory, attitude, subjective norms and perceived behavioural control are the three primary factors that shape an individual's behaviour and actions; thus, they can be used to predict actual behaviour.

Fishbein and Ajzen (1975) define attitudes as an individual's favourable or unfavourable evaluation of a behaviour—in this case, on-farm tree planting. These attitudes stem from beliefs about the likely outcomes of the behaviour and evaluations of those outcomes. Subjective norms refer to the perceptions of what others expect of an individual regarding engagement in a certain behaviour, whether they view the behaviour positively or negatively and whether others expect the individual to comply with these expectations. Ajzen (1991) describes perceived behavioural control as an individual's perception of their ability to perform a certain behaviour and whether they believe they can carry it out successfully. We use these three to classify our findings into attitudes, perceptions of external expectations and how these interact with perceptions of control over the tree planting process to derive response scenarios of farmers and crofters to various barriers and opportunities to agroforestry in Scotland.

The application of TPB has predominantly been quantitative, with researchers often ranking and weighing the relevance of certain attitudes and beliefs towards the propensity to engage in a given behaviour. For instance, Savari and Khaleghi (2023) combined TPB with the norm activation model to investigate pro-environmental intentions among farmers in Iran. Similarly, Atta-Aidoo et al. (2022) and Meijer et al. (2015) applied TPB to study the adoption of climate-smart agricultural practices and tree planting by smallholder farmers in Ghana and Malawi, respectively. These studies exemplify researchers' preferences for quantifying farmers' behavioural evaluations towards the adoption or intention to adopt agroforestry and other climate-smart practices. Our paper takes a qualitative approach to the use of this theory given the advantages of qualitative methods, including the ability to gather detailed insights into farmers' perceptions, experiences and contextual richness to help explain tree planting decisions among farmers in Scotland.

The TPB has been widely applied across numerous scientific disciplines, including health, agriculture, environmental conservation and education among others (Adams et al., 2022; Kautonen

et al., 2013; McEachan et al., 2011; Meijer et al., 2015). However, TPB assumes that individuals always make rational decisions based on available information, overlooking the influence of unconscious biases and emotions on behaviour. Additionally, its static nature fails to account for the dynamic changes in human attitudes, norms and perceived control over time (Paul et al., 2022; Sniehotta et al., 2014). Furthermore, TPB's focus on planned behaviour limits its scope, as it does not consider spontaneous or habitual decisions that occur without prior planning (Sniehotta et al., 2014; Zaikauskaitė et al., 2023). Regardless of these limitations, the TPB's cross-cultural applicability, ability to integrate multiple behavioural influencing factors and ability to guide necessary interventions or solutions to problems under investigation make it a valuable framework for understanding tree planting behaviours among farmers in Scotland (Adams et al., 2022; Ajzen & Schmidt, 2020; Bosnjak et al., 2020; Conner, 2014).

While concerns have been raised regarding its applicability across different cultural contexts, previous research has demonstrated that TPB's core constructs—attitudes, subjective norms and perceived behavioural control—remain useful in assessing behavioural determinants, even when cultural variations are present (Hassan et al., 2016; Leduc & Hansson, 2024). Specifically, subjective norms may be more susceptible to cultural differences, yet the qualitative approach adopted in this study allows for a nuanced exploration of how these norms manifest in decision-making processes within the Scottish context (Renzie & Klobas, 2008). Additionally, modifications to TPB have been proposed in prior literature to enhance its applicability across cultures, and this study acknowledges such considerations in its analytical approach (Renzie & Klobas, 2008; Leduc & Hansson, 2024). By employing TPB qualitatively, this study does not assume universal applicability across cultures but rather leverages the framework to systematically examine behavioural influences in a specific regional context. This approach enables a detailed understanding of how socio-economic and structural factors shape agroforestry adoption in Scotland, offering insights that may inform policy and practice within similar settings.

2 | METHODS

2.1 | Participant recruitment and data collection

In order to explore farmers' and crofters' experiences and attitudes regarding tree planting on farmland, semi-structured interviews were chosen as an appropriate data collection method. Given that there was a limited population of farmers in Scotland who had already adopted agroforestry, a survey would not have yielded a sufficient number of responses. Instead, we aimed for an exploration of the individual's motivations and insights via open-ended questions that allowed for in-depth discussions through flexible dialogue and probing for rich data (Denzin & Lincoln, 2017; Graves et al., 2017). We conducted interviews with 31 farmers and crofters in Scotland during the summer of 2023 and early 2024. This included 21 who already practised agroforestry and 10 non-adopters. The selection

of participants was based on opportunistic and snowball sampling, contacting farmers known to project partners (Scottish Forestry, Soil Association Scotland and Woodland Trust Scotland), internet searches for farms showcasing agroforestry, and recruitment via farmer/crofter networks until saturation was reached. According to Saunders et al. (2018), saturation in qualitative interviews is achieved when additional interviews do not provide new information beyond what has already been covered. The 10 non-adopters were recruited through internet searches. In our interviews with non-adopters, saturation was reached after the eighth interview.

As a purposive sample, representativeness of the farming population could not be achieved and was not the aim of the study design. However, we managed to recruit a diverse spectrum of Scottish farms, ranging from highly commercialized large-scale operations to small crofts, thereby reflecting the varied farm conditions, land-use priorities and economic models present across the agricultural sector. This range enables the study to present a range of perspectives and provide a nuanced understanding of agroforestry and general tree planting on Scottish farmlands.

The research received approval from the University of Aberdeen's Ethics Committee. All participants provided informed consent, indicating their understanding of the research project and their willingness to participate.

2.2 | Data collection and analysis

The interview guide included questions on the background of farmers and crofters, type of farm enterprise, agroforestry practices or tree planting designs adopted, year of starting to engage with agroforestry, tree species planted, perceived benefits, challenges, and financial and other forms of support (see S1). While some questions were standard for all participants, those not currently involved in agroforestry were asked a different set of questions designed to understand their perceptions and attitudes towards on-farm tree integration. Interviews were carried out in person (4) and online via Teams call (27) and lasted 50min on average. The audio recordings were transcribed and then coded in Nvivo qualitative analysis software. The coding scheme was developed based on the research questions and prior knowledge of barriers derived from the literature. Codes were refined based on additional detail emerging from the interview data, and themes developed to reflect attitudes, subjective norms and behavioural responses from different types of farmers.

3 | RESULTS

3.1 | Farm and participant characteristics

Although farm size is typically defined by production output or annual financial outcomes, understanding whether land availability influences the adoption of agroforestry required a different

approach. To contextualize our findings, we classified farms into three categories: small farms (50ha or less), medium-sized farms (between 50 and 250ha), and large farms (over 250ha).

Among the total 31 participants, 15 farms were exclusively livestock, particularly beef and sheep, while 15 had both livestock and arable (mixed), and 1 farm was exclusively arable (Table 1). Among the 21 adopters, 10 were exclusively livestock farms, 10 were mixed farms and 1 was exclusively arable. For non-adopters, five were primarily livestock, and 5 were mixed farms. The sample included four crofts, one community farming partnership and 26 farms. Most farmers reported experience or backgrounds in multiple fields. Those who grew up on farms also mentioned studying other disciplines such as engineering and accounting. Therefore, Table 1 should be interpreted with the understanding that it includes multiple counts. One participant is a researcher who also manages a farm. Another farmer is involved in consultancy and tree planting services in addition to managing their own farm.

3.2 | Farmers' attitudes towards on-farm tree planting

According to TPB, an individual's positive or negative evaluation of engaging in a behaviour influences their likelihood of performing that behaviour. In this section, we present the positive and negative attitudes of farmers that impact their tree planting behaviours. Our findings indicate that these attitudes include a general appreciation for the importance of trees, prospects for income diversification, additional income from tree planting incentives, doubting trees as preferential carbon sinks, prioritization of food self-sufficiency

TABLE 1 Participant characteristics.

Characteristics	Category	Frequency
Farm size	Small	5
	Medium	11
	Large	15
Type of farming	Livestock	15
	Arable	1
	Mixed	15
Land ownership	Owner-occupiers	26
	Tenants	5
Participants' background or field of expertise	Grew up on farm	14
	Agriculture course	10
	Environmental conservation	7
	Forestry	5
	Engineering	4
	Business administration	3
	Law	1
	Rural surveying	1
	Tree planting consultant	1

over tree planting and the belief that Scottish agriculture is already sustainable.

3.2.1 | General appreciation for the importance of trees

Our interviews reveal that typically farmers engaged in agroforestry—and even some non-adopters—hold a positive view of the benefits associated with integrating trees into their farming practices. This perspective was typical among most participants except some non-adopters. These positive perceptions are due to both anticipated and observed benefits of on-farm tree planting. Some farmers hold the view that the current generation must do better in terms of fighting climate change and the biodiversity crisis due to destructive behaviour of the past generations saying ‘My personal belief (...), is I just feel that out of all the efforts to save this planet from our unjust behaviour in the past, the most honest way, without any doubt, and the most fruitful way is to plant trees’. (Participant 5, adopter).

Furthermore, existing favourable perceptions of agroforestry encompass a variety of both observed and anticipated benefits such as enhanced resilience of farming systems, provision of fuelwood for biomass boilers, increased biodiversity, carbon sequestration, increased agricultural productivity, effective use of marginal land and the aesthetic enhancement of local landscapes. For instance, Participant 22 (adopter) observed ‘I think productively they’re very helpful in terms of shelter so we’re in a very windy area and quite often a very wet and windy area and we put our livestock in fields and there’s no shelter for them so I know that trees will provide good shelter from wind and rain for my animals’. Participant 14 (adopter) anticipated and observed increased biodiversity, enhancement or restoration of landscape aesthetics, and quality of habitats ‘But where there was virtually nothing on this land, we now are inundated in bird life, well, wildlife generally, and also, the flora has developed beautifully, really, where we’ve reduced stock or cut the stock out of at certain areas’.

When asked why they decided to integrate trees on their farms, new entrants to agroforestry consistently mentioned these anticipated benefits of trees as motivations for their interest in trees. ‘I mean why we’re doing this is for biodiversity, for shelter for the animals in the future, and our land is surrounded by trees; so there are parts of the field where our animals go and they adore them [trees]’. (Participant 5, adopter).

3.2.2 | Prospects for income diversification

Tree planting on farmland provides a number of multilayered benefits besides environmental and agricultural productivity enhancement. Our interviews reveal that farmers who planted trees often diversify their income sources to include economic streams like agricultural tourism. According to Participant 16 (crofting adopter), the trees on their farm enhance it as a tourist attraction offering

accommodation, camping and other services ‘...so we’ve done... like hosted the permaculture design course, which is usually a two-week or 72-hour course, which have attracted people from all around the world..., and now we’ve set up some accommodation for people to come and stay on the farm’.

3.2.3 | Additional income from tree planting incentives

Our interviews reveal that the availability of and access to incentives, both financial and non-financial support such as grant schemes, subsidies and tree planting advice, influence farmers’ perceptions towards tree planting. Some farmers mentioned that their awareness of funding schemes such as the Agri-Environment Climate Scheme (AECS), the Forestry Grant Scheme, Crofting Agricultural Grant Scheme (CAGS) and other local funding schemes influenced their tree planting decisions given the additional income from grants and subsidies. For example, Participant 13 (adopter) described how their main reason for adopting agroforestry was the availability of funding ‘But yeah, certainly things like grants are incentivising and ...obviously it’s quite expensive to establish woodland, so getting a payment to plant the trees and protect them and build fences and things means we can do more’. Various farmers also mentioned indirect financial support including the provision of seedlings, and tree planting and maintenance advice from local organizations as Participant 21 (adopter) noted: ‘Borders Forest Trust, and they will sort of supply tree shelters or maybe supply the trees’.

3.2.4 | Doubting trees as preferential carbon sink

Our findings reveal that negative perceptions of tree planting exist among both adopters and non-adopters. For instance, some farmers believe that tree planting for climate change is not an effective method for carbon sequestration, saying ‘But I don’t believe trees are the best way to mitigate or adapt to climate change. Trees do not sequester more carbon than the crops or grass we grow. It’s a ruse... You can sequester more carbon through annual grass we plant or by reducing fossil fuels going renewable’. (Participant, 24, non-adopter).

Among those not currently practicing agroforestry, there is a common argument for promoting other sustainable agricultural practices such as regenerative agriculture, organic farming and conservation agriculture. Additionally, some farmers argue that trees are slower at capturing carbon compared to grass and other livestock feed grown in large quantities in Scotland, viewing a focus on tree planting as a missed opportunity. They advocate instead for the sustainable management of crops and livestock. For example, Participant 29 (non-adopter) said that ‘... good farming practices create just as much carbon, if not more, as planting trees. Because after 20 odd years, trees don’t do anything for a start, there’s a little bit in the middle, and then after that, I believe it’s sequestered carbon’.

3.2.5 | Prioritization of food self-sufficiency over tree planting

Some participants hold the perception that tree planting competes with food production and therefore promoting tree planting will lead to overdependence on food imports in Scotland. According to Participant 29 (non-adopter), planting trees on their farm entails taking away good agricultural land that would rather be used for agricultural production instead of trees: 'Because my farm is quite good land, and I think it's a waste. I think we need to be self-sufficient in food and energy, and I think planting trees in good agricultural land is a sin, is a crime, because you won't to get it back'. Participant 26 (non-adopter) argued a further point: 'There's a sort of disconnect in many Scottish farms between the trees and the land and many farmers would see the trees as a bit of a menace because they provide shelter and shade on the crops and you know so they're not a great thing'.

3.2.6 | The belief that Scottish agriculture is already sustainable

Where farmers hold the view that agriculture in Scotland is already on a sustainable path, they perceive efforts to plant more trees under the guise of sustainability or carbon sequestration as a way for institutions promoting tree planting to secure more funding. Acknowledging that there are needs for improvements, Participant 26 (Non-adopter) argued that sustainability is already part of the wider Scottish agriculture, saying 'I think there's a narrative around agriculture that says it's not sustainable which I would really take exception to. I mean we are farming mixed systems with livestock and arable... Sustainable agriculture is the bedrock of Scottish farming'. This perspective was not expressed by any other participants, including those who did not adopt agroforestry.

3.3 | Agroforestry subjective norms

A farmer's subjective norms stem from their perceptions of what others expect of them to farm and manage their land, which then may influence their own tree planting behaviours. Our findings indicate that the need to go green, recognitions for green initiatives and perceptions of future market demands influence farmers' tree planting behaviours.

3.3.1 | The need to go green

Some farmers highlighted the importance of understanding their carbon footprints, driven by the perception that agricultural markets may soon demand carbon-neutral farm goods. Consequently, tree planting and carbon audits are seen as crucial measures to future-proof and increase farm income. For instance, Participant 13 (adopter) said 'I have a target that our farm will be carbon neutral by

2030, and if I can't get carbon neutral, I at least want to understand how close I can get. But for me... for me, the prize is to be able to sell beef which has no carbon cost attached to it'.

3.3.2 | Recognition for green initiatives

Being recognized for tree planting and other sustainable agricultural practices influenced some farmers either to start or increase tree coverage on farmland. Recognition for their efforts to transition to more sustainable production methods is also received positively. According to Participant 14 (adopter) 'We've just won an award, you might know that, for our new native woodland, (...) for the Scottish Finest Woodlands'. This award encouraged them to work with neighbouring farms to help them plant trees as well '...we do open days with the Woodland Trust here to try and get farmers and landowners to get on and plant some trees, which is slowly working by the way'.

3.3.3 | Perceptions of future market demands

Other respondents highlighted that planting trees on their farmland is an essential marketing component in the modern-day market systems. Farmers anticipate that their clients will be increasingly demanding sustainably produced products, thus having trees on farmland will become a good advertising point for farm produce. '... in this day and age, that (tree planting) seems to be a really positive sort of selling point for possible customers, that we are a working farm, looking to diversify, but we're sustainable because you know, we're looking after the environment with the trees that we put in'. (Participant 5, adopter). While this perspective was not shared by all participants, many adopters, along with a small number of non-adopters, acknowledged that the anticipated demand for sustainably produced food in future markets is a key factor influencing their decision to integrate tree planting into their farming practices.

3.4 | Perception of control over tree planting process

According to TPB, an individual's perceived ease or difficulty of engaging in a certain practice influences whether they would engage in such a practice or not. According to our findings, farmers' perceived control over the tree planting process and maintenance is influenced by knowledge of agroforestry, emerging trade-offs, policy environment, and accessibility and suitability of grant schemes.

3.4.1 | Knowledge gaps and uncertainties

New entrants to agroforestry encounter various uncertainties due to a lack of consolidated information about tree planting on

farmlands. Agroforestry knowledge gaps mostly pertain to access to available information useful for personal circumstances and preferences. Gaps include insufficient information about the selection and combination of tree species for specific soil types and locations, optimal planting designs, potential issues arising from tree planting and the trade-offs between tree planting and food security.

Some farmers hold the perception that agroforestry is the same as forestry. Our interviews reveal that the lack of distinction between forestry and agroforestry contributes to the perception that on-farm tree planting takes land out of agriculture and consequently leads to food insecurity or overdependence on food imports in Scotland. 'There's this tradition in the UK of farming and forestry as being two very different things' (Participant 12, adopter).

Given the diverse range of farm conditions such as soil properties and microclimate, coupled with personal objectives for planting trees, choosing the correct tree species for a specific farm with desired outcomes is challenging. While agroforestry information is available from various sources and in different formats, the lack of tailored information makes it difficult for some farmers to decide what to plant, thus stalling or making the tree planting decision difficult. 'What you really want to know is the soil type and what trees are possible... will grow in the type of soil that you've got'. (Participant 14, adopter).

Our interviews further show that the lack of information regarding possible challenges that would emerge after planting trees can make farmers view tree planting as a risky endeavour. Such challenges include the possible loss of investment capital should tree establishment fail due to diseases, pressure from deer browsing, livestock, adverse weather conditions or other reasons out of a farmer's control. New challenges may also occur when working with farm machinery around mature trees. '... mainly because it prevented you or it made it more difficult to take a silage cut, for example, you know, these trees aren't in a field that we take silage from anyway, but because they were imagining it, I suppose on their farms'. (Participant 15, adopter).

Availability and ease of access to support and advice about integrating trees on farmland has also been identified as a factor that can either enable or hinder farmers confidence and control over the tree planting process and the decisions to engage in agroforestry. Availability and access to tailored advice is uncertain for most farmers. Moreover, hiring consultants can be prohibitively expensive for farmers, especially small-scale ones. 'I do not like consultants on farms. I think that they leach money out of the system (farming) that I'd rather keep on the farm'. (Participant 14, adopter).

3.4.2 | Emerging trade-offs

Adopting agroforestry introduces extra activities on the farm. Farmers need to be sure that planting trees on their farm is going to have an economic benefit worth their time and financial investments

as well as the opportunity costs involved in tree planting and maintenance. When asked why they are yet to start planting trees, Participant 27 (non-adopter) said 'I suppose there's not enough financial incentive to make me do it. We have to prioritize what we can, what we're physically capable of doing in a day and if it doesn't pay it doesn't get done, that's how things work anyway'. While discussing whether availability of incentives would make them start planting trees, Participant 28 (non-adopter) pointed out that 'They have to be economically viable to justify doing them, that's the point of incentives to make me want to do [it]. I'm always keen to do environmental things but I can't do them if it's costing me money basically and taking up my time we should better spend somewhere else'.

3.4.3 | Policy-related barriers

Tree planting for tenant farmers remains a contentious issue in Scotland. Farmers who do not own the land they cultivate require consent from landowners to plant trees, although hedgerows are permitted. Participant 31 (non-adopter) said '...we can't because we're tenants on the farm, we can't plant any sort of... anything of any scale, in terms of trees. The lease... our lease won't allow us, and most leases won't allow a tenant to plant trees'. Given that tree planting and the returns from such an investment take many years, tenant farmers often do not view agroforestry as an attractive venture, except for hedgerows, which reach functional maturity more quickly.

3.4.4 | Navigating grant schemes

Although the FGS has seen significant changes to accommodate agroforestry options, farmers and crofters identified several barriers that discourage them from applying for funding. These include prescriptive conditions, complex and costly application processes, low payment rates, the bureaucratic consultation process and inflexibility in the application process.

The prescriptive nature of agroforestry options under the FGS has been a common complaint among farmers who have attempted to apply for these funding opportunities. Farmers and crofters noted that FGS conditions specify the types of tree species to be planted, planting density, and the minimum size of land eligible for a grant. 'So they're pretty prescriptive and they're not what our forestry advisor recommended for our plans'. (Participant 10, adopter). Some farmers mentioned that grant scheme conditions are often misaligned with their local environmental conditions, making it unattractive to pursue grant scheme applications. 'The funding is difficult because of our methods, I guess, methods of agriculture, or the design permaculture, it's notoriously difficult to pigeonhole and to put it in a box'. (Participant 16, adopter, crofter).

The application process has also been described as complex and costly. Farmers unfamiliar with the FGS application process find it

difficult to navigate, leading to the perception that most options under FGS are designed to favour large and rich farming enterprises. 'It is so difficult [FGS application] now that I wouldn't even attempt [applying for it]'. (Participant 7, adopter). Small-scale farmers are the most affected. 'We tried to apply for one [grant]. Unfortunately, we were too small!' (Participant 16, adopter, crofting).

Interviews highlighted the low payment rates of the FGS to adequately cover costs of tree planting. This also applies to protection and maintenance costs after planting, including repairing fencing. 'Well, part of the problem is that the available grant doesn't cover the costs anywhere near... So, there's not a lot of incentive for farmers to do that if the costs are more than double what the grant offers. And I think that was the biggest drawback'. (Participant 12, adopter, researcher).

One of the preliminary stages of the grant application process is the consultation step to establish the suitability of a site for tree planting. Farmers described this process as a fault-finding exercise to stop them from planting trees. 'The consultation can be quite onerous. You've got to consult archaeologists, landscape architects, wildlife experts... and if any of these bring up a concern, then it can kill the whole project'. (Participant 19, adopter).

Our interviews also found that the application process does not distinguish between small and large-scale farms. Farmers planning to plant 1 ha of trees or patches of trees across a farm are expected to go through the same application process as those planting larger areas of land (except environmental impact assessment required for over 20ha of planting). Participant 21 (adopter, consultant) feels it is necessary '... to speed up the process of applications and simplify it for small applications... It doesn't matter at the moment if you're planting one hectare or 100 hectares, you've got to go through the same process'.

3.5 | Behavioural response to agroforestry barriers

We distilled seven distinct responses (Figure 1) based on the interplay of farmers' attitudes, their perceived agroforestry norms, and level

of control and confidence over the tree planting and subsequent maintenance activities. These include (1) planting without grant support, (2) balancing between grant requirements and personal choices, (3) modifying original tree planting plans, (4) selling land to tree planting companies and organizations, (5) abandoning tree planting, (6) planting trees on an experimental basis or (7) choosing to plant hedges instead of trees.

Among those already engaged in agroforestry, the decision to plant trees despite various obstacles stems from multiple factors. When confronted with stringent grant scheme conditions, farmers who have a clear understanding of their tree planting preferences often opt to forgo funding and proceed according to their needs (6 adopters). These farmers typically possess a strong grasp of what is best for their land or the objectives of their tree planting efforts, a background in forestry or environmental conservation, or the financial resources to support tree planting independently as Participant 22 narrated 'No, everything that I've planted and guarded I've paid for myself, so all the fencing, all the guards, all the trees have all been paid for myself. Certainly, when I did it there was no grants available for this type of thing'.

For some, the challenges posed by grant schemes necessitate a balance between funding conditions and personal preferences (3 adopters). This might involve implementing various agroforestry designs on the same piece of land, with one parcel of trees funded by a grant scheme and another self-funded, reflecting personal choices. Farmers who navigate grant scheme-related barriers in this manner value both the financial support and their own preferences regarding tree species and planting methods on their farms. 'But the creation of that woodland doesn't really fit into any scheme. And then more recently, we've planted some shelter belts using the AECS, we planted this local agroforestry with grant from the Cairngorms National Park. We've done some other individual tree action, some riparian planting as well' (Participant 12, adopter).

Other farmers opt to adjust their initial tree planting plans to meet the requirements of grant schemes (3 adopters). These farmers often have personal preferences for what grows well on their land but still need funding to establish the trees. 'I wanted to have all

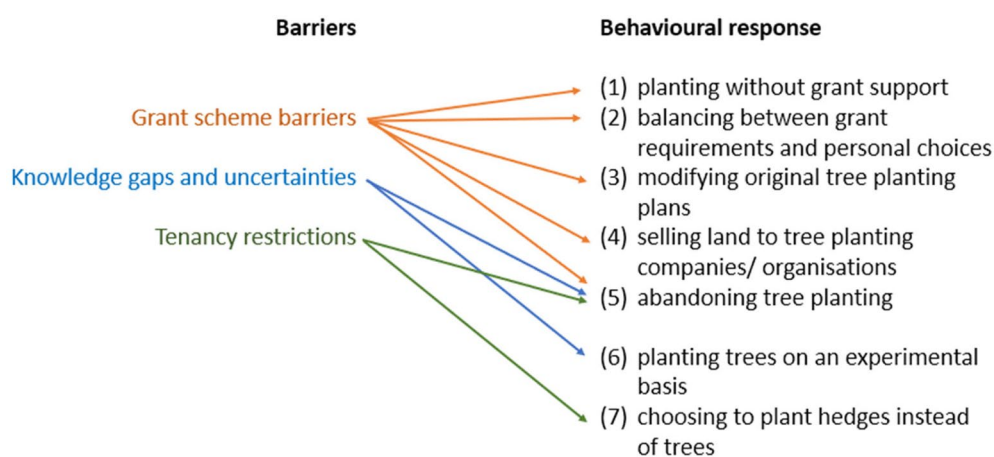


FIGURE 1 How farmers respond to agroforestry barriers.

the plants mixed and not two or three lines of birch or three lines of alder, or whatever. That didn't quite work out either. So, you can see now a strip going along and you've got ten ash and then a couple of oak. And so, it's not the way of mixing I was hoping for' (Participant 7, adopter).

Some farmers opt to sell part of their land to tree planting companies, perceiving that self-managed tree planting would incur additional operational costs or require expertise they do not possess (2 adopters). 'And we [sold] 150 hectares of our land for planting, for forestry, because we didn't want to do it ourselves because our experience of having anything to do with forestry has not been particularly positive'. (Participant 10, non-adopter).

Grant schemes may also prompt some farmers to completely abandon their tree planting ideas on their farms (10 non-adopters). Those who make this choice often lack strong personal preferences for tree planting, hold a negative perception towards tree planting or are primarily motivated by the additional income from grant schemes to diversify their farm enterprises. 'I mean, I wouldn't be against planting trees if there was a financial incentive to plant trees. It's something that I would look into, but I don't know, I can't do it now because incentives are not attractive enough'. (Participant 23, non-adopter).

Farmers who halt tree planting due to insufficient knowledge often resume once they gather enough information or receive guidance from an advisor (3 adopters). These farmers tend to attend tree planting events or join groups that promote tree planting. Conversely, some farmers prefer to treat tree planting as an experiment. This group, despite their limited knowledge, starts planting on their own to observe what grows well and which tree combinations meet their objectives. 'If you don't try you don't know... I suppose we're more hands-on, as a farmer with the trees and a lot of them [other farmers] are coming to trees as a new thing' (Participant 3, adopter).

While other barriers allow some room for tree planting, tenancy-related restrictions typically result in two outcomes: planting hedges (3 tenant farmers) or not planting anything at all (1 tenant farmer). For example, Participant 31 finds it difficult to do anything about trees due to their existing tenancy agreement 'We can't even... you know, dig a spade and put trees in without their permission, even some of the... the, you know, the trees that I put in, you know, along the waterside and things like that, I've got to get express permission to put them in'.

4 | DISCUSSION

Our analysis of barriers and opportunities to agroforestry adoption suggests that complex relationships exist between farmers' perceptions of tree planting on farmland and external challenges, such as the availability of attractive incentives and a conducive policy environment. The results indicate that barriers hindering tree planting for one farmer may not pose a significant challenge for another. This variation depends on individual perceptions of

agroforestry, perceived control over these barriers, and attitudes towards the expectations of others regarding tree planting.

Although extensive global research has demonstrated the effectiveness of agroforestry in enhancing farm resilience and productivity, the lack of specific evidence of benefits relevant to the Scottish context remains a significant barrier to its adoption. As our results show, farmers who perceive themselves as knowledgeable about tree planting are more likely to engage in it, even when faced with other obstacles. While the barriers to adopting agroforestry are largely socio-economic, having sufficient knowledge of the biophysical suitability and benefits of trees on farmland is essential to increasing agroforestry adoption in Scotland. As our results show, sufficient knowledge enhances farmers' behavioural control and confidence over the tree planting and maintenance process, motivating them to start planting trees or to extend coverage of what already exists on their farms. Graves et al. (2017) observed similar trends in England, concluding that enhancing farmers' knowledge of agroforestry could potentially increase the adoption of these systems.

Our findings indicate that positive attitudes towards tree planting among farmers are insufficient on their own to drive engagement in tree planting. The necessary confidence and control over tree planting come from knowledge about tree integration on their farms, including the selection of suitable tree species, understanding potential risks and assurance of positive environmental and financial outcomes. García de Jal'on et al. (2018), Raskin and Osborn (2019) and Graves et al. (2017) all found that positive perceptions of agroforestry lead to actual tree planting when farmers are confident that their specific objectives will be met, such as financial and environmental returns. Raskin and Osborn (2019) further argued that farmers motivated by financial returns might be discouraged from adopting agroforestry if it presents higher opportunity costs. Nevertheless, farmers who have both positive perceptions and the necessary knowledge are more likely to engage in tree planting than others.

Despite the availability of the FGS and other financial incentives, most farmers remain unaware of these grant opportunities. In addition to recommending new agroforestry options and enhanced payment rates under the FGS, the Cumulus (2024) also advocates for incorporating these options into existing agricultural payment schemes that farmers are already accustomed to. The Woodland Trust (2022) noted in their report on integrating trees on farmland in Scotland that agroforestry options under the FGS are largely unknown to most farmers, as these grants fall outside the typical farm subsidies received by Scottish farmers. Similarly, Staddon et al. (2021) found that grant schemes and other financial incentives have only motivated a small proportion of farmers to plant trees. While perceptions towards tree planting are significant factors, the unfamiliarity with grant schemes among farmers may also explain why these schemes have not substantially increased agroforestry adoption in Scotland.

Based on recommendations from recent research on farmer adoption of agroforestry (McIntosh, 2023; Soil Association Scotland, 2020; Woodland Trust, 2022), significant changes have

been made to the agroforestry options in FGS. However, it remains to be seen whether these new changes are attractive enough for eligible farmers, particularly those with small farms who rely on funding to plant trees.

Among non-adopters of agroforestry, their perceptions of the importance of trees and the potential benefits to their farming enterprises seem to overshadow grant scheme-related barriers. Despite the availability of funding, those who view tree planting as an ineffective method for carbon sequestration would need a shift in attitude rather than more attractive grant schemes. Staddon et al. (2021) argued that farmers with positive attitudes towards tree planting would proceed with planting, even if grants are unknown, unavailable or too restrictive. Our findings support this argument.

Farmers under various types of tenancies require significant policy shifts to enable them to plant trees. Current tenancies under the Agricultural Holdings (Scotland) Act 2003 mandate that tenants obtain written consent from their landlords before engaging in tree planting, as trees alter property characteristics. Although the Act permits tree planting as a non-agricultural diversification activity, it remains unclear what size of planting qualifies as non-agricultural or whether such planting is eligible for any of the FGS options.

A similar situation arises for landowners who let out land. The Agricultural Holdings Act requires them to obtain written consent from their tenants to use the tenanted land for tree planting. Due to the need for greater control over their land, flexibility, risk management and uncertainties in the land regulation environment, shorter tenancy agreements such as Short Limited Duration Tenancies (SLDTs) are increasingly preferred in Scotland, further complicating tree planting on tenanted land.

Even when written consent is granted, it remains unclear how the benefits of the tree planting investment would be shared between the landowner and the tenant, given that trees are a long-term investment that outlasts most tenancy periods. Recognizing these challenges, the Scottish Government's consultation paper (Scottish Government, 2022) proposed a new flexible tenancy framework called the Land Use Tenancy. This framework aims to allow multiple land use activities, including agroforestry, with stipulations on benefit sharing, tenancy termination and key terms for agreements between landowners and tenants at the onset of the tenancy.

5 | CONCLUSION

Understanding the complex nature of agroforestry, along with the barriers and opportunities that influence its adoption, is essential for Scotland to fully leverage its multifaceted benefits. This paper outlined and described how various factors influence farmers' behaviours towards adopting agroforestry. While the lack of funding or awareness of financial incentives remains a significant barrier, our findings suggest that the slow and low adoption of agroforestry also depends on how a farmer's personal preferences and knowledge of tree planting and its benefits interact.

The perception of how agroforestry may positively impact a farming enterprise can heavily influence a farmer's decision to engage in tree planting. Changing the perceptions of farmers, crofters and land managers is a complex endeavour, but initiatives aimed at disseminating agroforestry information to specific groups of farmers may significantly contribute to this change. Such initiatives could include information that highlights the differences between commercial large-scale forestry and agroforestry and how agroforestry can positively contribute to agricultural resilience and financial outlook. This may help reduce risk perceptions among farmers who still believe that agroforestry could lead to the loss of agricultural land, increase Scotland's dependence on imported food and worsen declining farm income.

Access to relevant tree planting information, particularly regarding the integration of trees and agriculture, remains a persistent challenge for farmers looking to start agroforestry. While information about agroforestry or tree planting in general exists in Scotland, farmers and land managers often find it difficult to access and tailor it to their business. Making this information readily available in easy-to-digest formats could significantly improve the adoption of agroforestry in Scotland. For instance, easy-to-use decision support tools that provide case studies of agroforestry practices across Scotland may serve as a valuable resource where farmers, land managers and crofters can explore specific examples of agroforestry cases relevant to their circumstances. Additionally, various institutions are already hosting on-farm agroforestry events aimed at introducing farmers to agroforestry. These efforts need to be intensified to ensure that farmers can make informed decisions regarding agroforestry.

This paper also highlights that tenant farmers are often sidelined in agroforestry, as most existing tenancy agreements do not permit them to plant trees on tenanted land. The proposed Land Use Tenancy could significantly address this challenge. However, the Scottish Government and its stakeholders must continue to explore other pathways to facilitate tree planting on tenanted land. This may include clear guidelines on how agroforestry can be implemented in cases where tenancy agreements are significantly shorter.

While the FGS has seen improvements in payment rates, planting density and other conditions, challenges such as the complexity of the application process, their prescriptive nature and cash flow issues remain. Increasing agroforestry options under the FGS, making tree planting more profitable through mechanisms like carbon credits and subsidies, and implementing measures to reduce the risks of financial losses are essential steps to further promote agroforestry adoption.

AUTHOR CONTRIBUTIONS

Katrin Prager and Albert Mvula conceived the idea. Albert Mvula and Katrin Prager collected and processed the data. Josie Geris and Katrin Prager provided supervision and funding. Albert Mvula led the writing of the manuscript with contributions from Katrin Prager. Albert Mvula and Katrin Prager led the revisions of the manuscript. All authors contributed critically to the argument and interpretation,

agreed to be accountable for the manuscript and approved its submission for publication.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available upon reasonable request from the second author (KP). We cannot make public the full interviews (even fully anonymized) because interviewees may be recognizable from seemingly insignificant details we cannot anticipate, and key details of most adopters are available on the FARM TREE Info Tool (<https://glensaugh.hutton.ac.uk/research-data/farm-tree-integrating-trees-agricultural-land>).

ORCID

Albert Mvula  <https://orcid.org/0000-0002-5155-2935>

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Interview schedule

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