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Motivation and perception of farmers on the benefits and challenges of agroforestry in Sweden (Northern Europe)

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Abstract Agroforestry systems provide multiple benefits for human wellbeing and biodiversity; however, their diversity and spatial distribution has sharply declined across Europe. This study focuses on agroforestry farms in Sweden. The aim of the study was to explore farmers' motivations to start agroforestry, what benefits farmers attributed to their agroforestry farms and perceived challenges to practising agroforestry in Sweden. In total, 13 farms that practise various agroforestry forms were selected as case studies. A focus group, semi-structured interviews and field observations were used for data collection. We identified four types of agroforestry systems such as silvopasture, silvoarable, forest farming and forest gardens established on different land such as forested or agricultural land. All studied agroforestry farms were small but had complex spatial and temporal arrangements of crops, trees and animals, which were crucial to generating multiple benefits. Our results show that the multifunctionality of agroforestry systems resulted from farmers' desire to design such systems. Farmers' intentions to get foods and materials from their farms were always intentionally unified with multiple ecosystem services. We argue that agroforestry farmers are designers of multifunctional landscapes, as they deliberately organised their farming activities to get a bundle of ecosystem services belonging to all four categories—provisioning, regulating, supporting and cultural. However, the complexity of agroforestry management, lack of technologies suitable for small-scale agroforestry farms, limited plant materials (including seedlings) and limited knowledge about how to do agroforestry challenged the scaling up of agroforestry practices.

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Introduction

Agroforestry denotes the multifunctional land-use system that deliberately integrates woody vegetation with crops and animal production through diverse and simultaneous land-management activities, resulting in the provision of multiple tangible and intangible benefits (Mosquera-Losada et al. 2009; Plieninger et al. 2015; Fagerholm et al. 2016; Torralba et al.

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2018; Elbakidze et al. 2021). Agroforestry practices often overlap with each other temporally or/and spatially, creating multifunctional cultural landscapes in Europe. Traditionally, agroforestry systems have been the key elements in the European cultural landscapes for centuries (Eichhorn et al. 2006; Nerlich et al. 2013; Plieninger et al. 2015).

In the EU, agroforestry systems currently occupy 15.4 million hectares, or 3.6% of the union's total territorial area (den Herder et al. 2017), 98% of which are organised under different forms of livestock agroforestry and 2% under arable agroforestry. Many studies confirm that agroforestry systems simultaneously provide multiple benefits for human wellbeing and biodiversity (Jose 2009; Smith et al. 2012, 2022; Tsonkova et al 2012; Torralba et al. 2016; Abbas et al. 2017; Bentrup et al. 2019; Sollen-Norrlin et al. 2020). The IPCC reports (2019, 2022) claim that agroforestry has the potential to combine production with less adverse effects on the environment than conventional agriculture and forestry, as well as provide multiple benefits such as mitigation and adaptation to climate change, reduced land degradation and desertification as well as improved food security. However, the diversity and spatial distribution of agroforestry systems have been in sharp decline across Europe (Eichhorn et al. 2006; Plieninger et al. 2015; Almeida et al. 2016; Godinho et al. 2016), a trend caused mainly by intensification of conventional agriculture and forestry, abandonment of agricultural land and encroachment due to urban sprawl (Mosquera-Losada et al. 2009; Plieninger et al. 2015; Garrido et al. 2017a, b; Barthel et al. 2019). There are also multiple internal challenges in maintaining agroforestry systems, such as higher labour input due to the high complexity of these land-use systems and higher costs for investment, maintenance and administration in association with holistic management decisions (Graves et al. 2009; Garcia de Jalón et al. 2018), compared with conventional agriculture and forestry (Sereke et al. 2015; Garcia de Jalon et al. 2018). Often contradictory public policy measures (e.g., CAP) fail to address the multifunctionality of agroforestry landscapes and have been considered unfavourable towards agroforestry practices (Fragoso et al. 2011; Almeida et al. 2016; Pinto-Correia and Azeda 2017; Santiago-Freijanes et al. 2021). Serious concerns are expressed by multiple actors and stakeholders, including decision-makers and academics, that under current policies and trends in land use, agroforestry practices will continue to decline in the EU (Godinho et al. 2014; Almeida et al. 2016; Fischer et al. 2018).

This paper explores the motivations of farmers to start practising agroforestry, the benefits they attribute to their agroforestry systems and the challenges they experienced to practise agroforestry in Sweden. This study is particularly important within the context of new policy demands at multiple levels related to diversification of approaches to land management (e.g., UN Environment 2019; IPBES 2019). Conventional approaches to land management, including agriculture and forestry, are often characterised by a predominant bias towards the provision of products and services with market value (Reid et al. 2005; McAdam et al. 2009). Other benefits with no market value, i.e. biodiversity and traditional knowledge, are usually given less priority. By contrast, numerous policy documents have pointed out the need for a balanced development approach that embraces all dimensions of sustainability, including both material and immaterial values, and the full range of ecological, economic and socio-cultural benefits to accommodate economic development and human wellbeing (see e.g. UNEP 2019; IPBES 2019). Agricultural policy in the EU has gradually refocused from supporting large-scale conventional agriculture toward restoration of multifunctional agricultural landscapes, and the contribution of agroforestry to achieving high-level environmental and societal goals is reflected in several policy documents within different sectors (Agroforestry network 2018; Fischer et al. 2018). Agroforestry primarily receives support through the CAP, although the significant ecological and social value of agroforestry was acknowledged at the EU level only in 2005. For the period 2020–2027, the European Green Deal will guide the CAP, alongside the Farm to Fork Strategy (EU 2020a) and the Biodiversity Strategy for 2030 (EU 2020b), both of which address agroforestry and its multifunctional potential. According to the Biodiversity Strategy, "the uptake of agroforestry support measures under rural development should be increased, as it has great potential to provide multiple benefits for biodiversity, people, and the climate" (EU 2020b).

Given the impending EU policies, it is imperative to explore the diversity of agroforestry systems in Sweden and comprehend the potential benefits they may offer. During the last decade, there has been growing interest in agroforestry on the part of different stakeholders in Sweden, while in-depth studies on agroforestry systems, mainly newly established ones, are still scarce in Sweden and Europe's North in general. A systematic review by Fagerholm et al. (2016) indicates that current agroforestry research hotspots are concentrated in the Mediterranean region, the UK, and France, with a notable dearth of studies from Northern Europe. In high-income countries, the majority of studies have been conducted in the US (Castle et al. 2022), with only six out of 290 studies conducted in the Nordic countries. Studies on agroforestry in Sweden have predominantly focused on various forms of traditional silvopastoral systems, such as wood pastures (Sandberg and Jakobsson 2018), reindeer husbandry (Valinger et al. 2018), and the system of summer farms, based on animal husbandry on outlying fields covered by boreal forests since arable land is often scarce (Eriksson 2011; Axelsson Linkowski 2017). Furthermore, Garrido et al. (2017a) identified multiple benefits attributable to traditional oak wood pastures in Sweden by diverse stakeholders from the civil, private, and public sectors at the local and regional levels. They demonstrated that provisioning and cultural ecosystem services were perceived as the most important from the perspectives of different stakeholder groups. Kumm and Hessle (2020) conducted a comparison of profitability between spruce plantations, natural afforestation through planting birch trees, and beef production on mosaic forest-pasture land. With larger herds of animals (more than 20), the beef production alternative proved to be the most profitable, with the exception of spruce plantation in southern Sweden.

A few studies have analysed newly established and modern forms of agroforestry such as forest gardens in Europe's North. For example, Almers et al. (2018) focused on the benefits of such gardens for outdoor pedagogy for children, and concluded that forest gardens were more accessible and provided more opportunities for children's creativity compared to forest excursions. In Vlasov et al. (2018), forest gardens were understood as grassroots innovations and the initiators of forest gardens as grassroot "ecopreneurs" in Sweden. Björklund et al. (2018) explored the establishment of forest gardens and Schaffer et al. (2019) investigated three types of modern agroforestry systems and what would be needed for such systems to grow beyond the niche level. Both studies comprised participatory action research (PAR) in which farmers at 12 farms in Sweden were included (Björklund et al. 2018; Schaffer et al. 2019).

Using agroforestry farms as case studies in Sweden, this study focuses on the following research questions: Why do farmers practise agroforestry? What benefits do they attribute to their agroforestry farms? What challenges are associated with establishment of agroforestry farms?

Methodology

Key concepts

In our exploration of benefits attributed to agroforestry systems, we used a multifunctional landscape concept. Conceptually, an agroforestry landscape as a cultural landscape can be understood as a geographical unit that holds significance for local communities and various stakeholders, encompassing dimensions ranging from biophysical and socio-cultural to perceived aspects (Antrop 2004). The biophysical components involve all natural elements, while socio-cultural components encompass cultural legacies, heritage, and the people interacting with the natural elements (Angelstam et al. 2013). Multifunctional landscapes are defined diversely. We adhere to the definition put forth by Lovell and Johnston (2009), who characterise these landscapes as providers of a diverse array of environmental, social, and economic functions. Human activities often alter natural landscapes to serve single functions, leading to landscape homogenisation (Jongman 2002; Fischer and Lindenmayer 2007; Garcia-Martin et al. 2021). In contrast, multifunctional landscapes, as opposed to monofunctional ones, integrate human production with ecological functions, maintaining critical ecosystem services and biodiversity (O'Farell and Andersson 2010).

To comprehensively map all benefits attributable to agroforestry systems, we employed the ecosystem service concept. The ecosystems approach, particularly the cornerstone concept of ecosystem services, has emerged as the prevailing paradigm in research on people-nature relationships since its initiation by the Millennium Ecosystem Assessment (Reid et al. 2005). Numerous studies have empirically assessed ecosystem services provided by agroforestry systems, confirming their multifunctionality and relevance for both biodiversity and human well-being (Jose 2009; McAdam et al. 2009; Garrido et al. 2017a, b; Hartel et al. 2017; Torralba et al. 2018; Kay et al. 2019; Castle et al. 2022). Ecosystem services, defined as the benefits people obtain directly or indirectly from ecosystems, encompass provisioning, regulating, cultural, and supporting services (MA 2005). Ecosystem services research traditionally emphasises the supply side, employing spatial analyses of different land covers and other spatially explicit data to quantify ecological characteristics for the provision of a specific ecosystem service. However, recent studies underscore the importance of addressing the demand side of ecosystem services (Bagstad et al. 2014; Fagerholm et al. 2019; Plieninger et al. 2019), considering diverse stakeholder perspectives and interests regarding ecosystem services (Garrido et al. 2017a, b).

Despite its widespread use, there is substantial critique arguing that the ecosystem services framework oversimplifies the complexity of people-nature interactions inherent in agroforestry systems (Lele et al. 2013; Norgaard 2010; Elbakidze et al. 2021). Some scholars propose alternative terms, such as "social-ecological services" (Huntsinger and Oviedo 2014) or "landscape services", to better capture the multiple tangible and intangible benefits provided by agroforestry systems. Moreover, these discussions underscore the crucial roles of farmers and land managers in generating services (Garrido et al. 2017a, b). Being aware of such discussions, we have paid particular attention to how farmers explained benefits provided by their agroforestry farms and how they perceived their role in generating these benefits.

Finally, we employed the concept of a multifunctional landscape to explore farmers' motivations for practising agroforestry. The motivation to support environmental sustainability through agroforestry was evident when farmers referred to maintaining biodiversity, improving soil quality, or implementing measures to adapt to or mitigate climate change. Sustaining the economic functions of agroforestry farms was considered when farmers organised their practices to support their household economies. Lastly, when farmers aimed to preserve landscape values and traditional knowledge associated with agroforestry practices, this activity was categorised as landscape stewardship to sustain the socio-cultural functions of agroforestry systems.

Agroforesrty in a Swedish context

Historically in Sweden, silvopastoral systems have been practised for at least 2 500 years BP (before the present). During this period, people cleared forests to create fields for grazing domesticated animals in the outlands (Dahlström et al. 2006; Kumm and Hessle 2023). Beyond grazing, forests were utilised for hunting, collecting firewood, and sourcing construction materials. Currently, agroforestry occupies 1.1% of the territorial area, or 15.2% of all utilised arable land (den Herder et al. 2017) in Sweden, and 99% of the agroforestry systems are categorised as silvopastoral systems. However, recently there are growing numbers of pioniers developing new forms of agroforestry, among them systems of alley cropping, mixing fruit trees with cereals or pasture, and edible forest gardens. The number of farms with this type of production, its scope and financial contribution to the farms' economy is still relatively small. Since 2016 there is an active NGO (Agroforestry Sverige) comprisning farmers, agricultural advisors, reserachers and other actors aming at promoting agroforestry in Sweden (Agroforestry Sverige 2023).

In the Swedish rural development support system for 2023–2027, within to the EU common agricultural policy there is currently no support for establisment of agroforestry systems at farms. Neither is agroforestry eligble for CAP direct payments (Jordbruksverket 2022; EU CAP Network 2023).

Agroforestry farms as case studies

To address our research questions, we employed three criteria for the careful selection of agroforestry farms for in-depth study. The first criterion involved choosing the most experienced agroforestry farmers in Sweden, with a minimum of five years of hands-on agroforestry experience. This criterion was established in recognition of the need for a substantial time frame to draw meaningful conclusions, especially in the context of tree planting within newly established agroforestry systems. The second criterion aimed to ensure a representative sample by selecting agroforestry farms that collectively showcase the diversity of agroforestry systems in Sweden. This approach allows us to pursue a comprehensive understanding of various agroforestry practices within the country. The third criterion focused on selecting farms where revenue extends beyond the household level, addressing the broader food security dimensions of agroforestry in Sweden. Considering that approximately 50% of all food in Sweden is imported and distributed primarily through stores and the broader value chain, it is crucial for agroforestry production to contribute beyond individual households to make a substantial impact on the country's food security.

We applied a snowballing method to select agroforestry farms, through contacts established during agroforestry conferences and other events in Sweden, and with the help of experts from the Swedish University of Agricultural Sciences who have studied agroforestry systems in Sweden.

In total, we selected 13 farms (F1–F13) which are located in 13 municipalities in the central-southern part of Sweden. From a biophysical perspective, two farms are located in the boreal zone, eight in the boreal-nemoral zone (mixed forests), and three in the nemoral vegetation zone (deciduous forest). All farms are located in cultivation zones 1–5, which refer to the Swedish system for classifying the hardiness of plants (Sweden Plant Hardiness Zone Map 2022, www.plantmap/). The growing season is 170–215 days long; the summer mean temperature is 15 °C, and the winter mean is − 3 °C. The yearly precipitation is ~ 700 mm (Sveriges meteorologiska och hydrologiska institut 2023, www.smhi.se/). The soils are constituted by various types of clay and sand with different soil organic matter content.

The selected farms practised agroforestry which belonged to four categories—silvopasture, silvoarable, forest farming and forest gardens (Mosquera-Losada et al. 2018a, b), and ten farms (out of 13) combined several of these agroforestry systems (see Appendix 1).

Farms employing *silvopasture* agroforestry system integrated wooded elements with forage and animal production, as outlined by Mosquera-Losada et al. (2018a, b). Our identification revealed various forms of silvopasture, including *forest grazing, wood pasture,* and *fruit trees integrated with fodder/grazing*. In the forest grazing system, denser forests were utilised for grazing various animals, such as sheep, cows, pigs, and horses. This practice was observed on five farms (F1, F2, F4, F12, F13), each ranging from 40 to 2 000 hectares in size. Clear-felling forest management, particularly in spruce forests, was employed, and certain areas were designated for pig grazing. Additionally, two farms (F2, F4) implemented continuous cover forestry along with sheep and cow grazing in mixed forests. *Wood pasture agroforestry*, characterised by grazing sheep and cows in pastures with a lower tree density compared to forest grazing, was identified on five farms (F2, F3, F4, F9, F13). Pastures in this system often overlapped with patches of semi-natural grassland.

The *silvoarable* agroforestry system incorporated widely spaced woody vegetation that was intercropped with annual or perennial crops, as outlined by Mosquera-Losada et al. (2018a, b). Among the selected farms, *alley cropping* was the predominant practice within this system.

Alley cropping involved the cultivation of rows of tree crops (such as apples) and shrubs (including hazelnuts and a mix of berries) or mixed polycultures of trees and shrubs. These were strategically placed between fields of annual crops. The identified alley cropping systems in our study, each at least five years old, represent a unique presence in Sweden. The practice of alley cropping was observed on two farms (F1, F11). Farm F1 dedicated 1 hectare to alley cropping, while farm F11 allocated a more extensive area of 7–8 hectares to this agroforestry system.

Forest farming occurs in forested areas, integrating forest and agricultural lands for the production or harvest of natural standing specialty crops with medicinal, ornamental, or culinary uses (Mosquera-Losada et al. 2018a, b). In our study, forest farming encompassed practices utilised alongside forestry, intentionally producing various products on forest land. Such practices included the cultivation of mushrooms on logs, as well as planting walnut trees, fruit trees, shrubs and herbs into existing forests. While Mosquera-Losada et al. (2018a, b) highlight the significant potential of forest farming as an agroforestry practice, to our knowledge, our study represents the first documentation of forest farming in Sweden. Forest farming was practiced on three farms (F2, F6, F10), ranging in size from 2 to 40 hectares. On F2, oyster mushrooms were cultivated on logs within a mixed forest. F6 planted walnut trees in a birch forest, and F10 implemented forest farming by planting shade-tolerant species such as herbs, vegetables, berries, and nuts in a mixed forest. Continuous-cover forestry practices were observed in all three farms.

Forest gardens, aligning with the homegarden/kitchen garden (Mosquera-Losada et al. 2018a, b) or food forest category (Sharma et al. 2022; Park et al. 2018; Albrecht and Wiek 2021), represent an agroforestry system that integrates trees/shrubs with vegetable production, typically in urban and peri-urban areas. The term "forest garden", as used by the interviewed farmers in our study, aligns with the concept presented by Crawford (2010). Within our investigation, forest gardens were recognised as intercropped polycultures of edible woody perennials, incorporating a diverse array of elements such as fruits, nuts, berries, vegetables, herbs, flowers, and occasionally, components like hens and trees intended for timber, fiber, or fuel production. These gardens were thoughtfully designed as two- to five-layered systems, often mirroring the characteristics of the forest edge zone and the mosaic structure found in such ecotopes. Our study identified three distinct sub-categories of forest gardens. The first sub-category, termed "small forest gardens", ranged from 60 to 200 m^2 in size. These gardens featured five layers of perennials and boasted a rich species diversity of 30–100 species of edible woody perennials, including fruits, nuts, berries, vegetables, herbs and flowers. The second sub-category, known as "middle-size fruit gardens with hens", ranged from 200 m^2 to 0.5 hectares in size. These gardens featured 2–3 layers with 10–20 species of trees and shrubs. In place of a cultivated ground layer, hens were integrated into the system. The third sub-category, termed "food forest", varied in size from 0.5 to 7 hectares. These extensive gardens featured 2–5 layers of woody perennials, with one layer often focused on high-quality timber production. Intercropped with 25–400 edible species, these food forests served various purposes, functioning either as kitchen gardens for household needs, for commercial purposes, or as a combination of both. *Forest garden agroforestry system* was practised on ten farms (F1–F10), ranging between 2 to 230 hectares in size.

In total, 26 individuals were engaged in agroforestry practices on the studied farms, and for the purposes of this study, they are referred to as "farmers" since all of them were involved in food production. The distribution of farmers across age groups and living situations is as follows: fourteen farmers were in the age range of 30–45 years, eight farmers were between 55 and 65 years, and four farmers were in the 70–80-year age group. Among the farmers, five had families with small children, five (aged 50+) lived without children on the farm, and three farmers did not reside on the farm at all. Regarding land ownership and management structures, ten farmers (F1–F5, F7–F10) owned the land they utilised, two farmers (F11, F12) leased the land, and one farmer (F6) operated on land owned by a foundation. Additionally, three farms had specific characteristics within the study context: F13 utilised 2 000 hectares within a vast nature reserve where silvopasture was integrated into land management; F11 served as a university test site for silvoarable systems, and F6 functioned as a learning site for folk high school programs. Furthermore, F10 was managed by a group residing in the same village, collaboratively working on various agroforestry projects.

Data collection and analysis

In a first step, a focus group session was conducted in November of 2019 with five farmers, three men and two women, representing three farms (F1–F3). The focus group's purpose was to discuss the purpose, experiences, challenges and potential for scaling up of agroforestry systems that these farmers have practised. The focus group session lasted for two hours. The discussions were recorded and later transcribed.

In a second step, semi-structured interviews were conducted with nine men and seven women, representing ten farms (F4–F13) between November 2019 and February 2020. The interview manual contained questions related to agroforestry systems that respondents conducted; farm products; varieties of trees and plants, farm productivity, motivations for doing agroforestry, possibilities for scaling up production; and the main constraints and opportunities for practising agroforestry (see the interview manual in Appendix 2). The interviews took from 30 to 60 min. All interviews were conducted by telephone, recorded and transcribed, except one which was conducted by e-mail (F8).

Finally, field observations were conducted on studied farms to learn more from each farmer's own experience about their agroforestry systems and to get an overview of the whole farm, not only the agroforestry system. Example of issues discussed during observation were the establishment of various perennial crops and trees, what land and location in the landscape could be most suitable for various agroforestry systems, what design regarding intercropping would be the best, challenges with the harvest, pests (voles) and so on. The field visits were guided by farmers and lasted up to four hours each.

All interviews, notes from field observations, and the focus group discussion were analysed using qualitative content analysis (Bryman 2008). All collected data were fully transcribed, and all transcripts were imported into the NVivo data analysis software. Using NVivo, we first grouped the data into six nodes organised after the content of the respondents' answers. After the initial analysis, we consolidated the findings into three nodes corresponding to the three research questions: motivations for practising agroforestry, perceived benefits attributed to different agroforestry systems, and perceived challenges associated with agroforestry. We did not have direct questions employing concepts such as ecosystem services, nor did we provide examples of challenges related to climate change or financial constraints. These themes were spontaneously addressed by the respondents. Additionally, each node was further divided into sub-nodes organised on the basis of the respondents' answer content. For instance, the node "Motivations" included four sub-nodes: (1) sustaining the household economy, (2) supporting environmental sustainability, (3) mitigating and adapting to climate change, and (4) landscape stewardship. All relevant data from each interview were extracted and organised within these nodes and sub-nodes.

The qualitative data related to the perceived benefits from agroforestry farms was converted into different categories of ecosystem services. We applied the Ecosystem Service Coding Protocol (CP) proposed by Wilkinson et al. (2013), which allowed for coding consistency of ecosystem services among all analysed interviews. The CP included four categories of ecosystem services: supporting (coded A), provisioning (B), regulating (C) and cultural services (D) (Reid et al. 2005). Appendix 3 illustrates the transformation of respondents' responses into various ecosystem services, grouped into four distinct categories.

Results

Motivations of farmers

All farmers expressed multiple motivations for practising agroforestry, among which we identified four broad groups: (1) to sustain the household economy, (2) to support environmental sustainability, (3) mitigation and adaptation to climate change, and (4) landscape stewardship.

Sustaining a household economy was an important motivation to practise agroforestry, but it was always combined with other motivations. Producing good yields was at the core for farmers in the studied farms: "*The ambition with the farm is to contribute positively to the ecosystems and at the same time produce useful products. The aim is to go from producing more to how to produce and developing methods that can use the ecosystem services*" (F1). However, getting good yields from recently established agroforestry farms took time. Therefore, generating income from off-farm jobs was necessary as well for some farmers: *"The aim is to generate income for us, to make a living from the harvest, the processed products and selling seedlings from the forest garden, and our eco-café, and educational activities such as courses, lectures and guided tours. We also do (consultancy) ecosystem-based management and nature conservation for other producers"* (F8).

Farmers employed various business models or strategies to sustain their farm economy. Many farms integrated agroforestry with other types of production, such as annual crops and forestry. Some generated income not only through selling products but by utilising the farm as a site, indirectly "selling" the site and agroforestry knowledge through activities like courses, events, tourism, and selling seedlings and products in their own cafés or restaurants. Others engaged in off-farm part-time jobs, consultancy, or teaching, leveraging their knowledge of agroforestry systems. Some respondents had only recently founded their farms, acknowledging that planting trees takes time, and thus employed alternative strategies for maintaining their livelihood. For instance, F1 conducted a rough estimation, comparing prices for berries with cereals in their alley cropping system, noting that berry prices were ten times better per kilo than cereals. F7 focused on high-quality timber, recognising that favourable prices could be charged in Germany. F2 highlighted the importance of subsidies for forest grazing in sustaining the farm economy. F6 and F10 emphasised that their primary goal was not to sell products; instead, they generated income through education and events on the farm. However, F13 faced challenges in selling meat locally to the public sector due to procurement contract issues. F9 transitioned from commercial to self-subsistence production due to family circumstances but planed to return to commercial fruit production in about ten years. This farmer explained that the trees would still be there and that they would likely be more productive after an additional decade. Additionally, two couples were in receipt of pensions, with one couple initiating their agroforestry project post-retirement some 15 years ago. Among two other couples, one of the persons in the couple respectively received pension income.

To support environmental sustainability was a motivation expressed explicitly by 11 out of 13 farmers. Farmers referred to multiple aspects of environmental sustainability, such as maintaining biodiversity, improvement of soil fertility, recycling organic matter and furthering animal welfare. None of these farms used pesticides or chemical fertilizers, and three farms were certified as organic farms. For example, some farmers explained that supporting biodiversity was one of their core priorities in practising agroforestry: *"To keep the richness of biodiversity is more important than to produce for selling; this is a shift in mindset that has happened since 2011 when we started"* (F9).

Seven farmers expressed the importance of agroforestry for both climate mitigation (e.g., carbon storage) and adaptation to extreme weather conditions. As one farmer said: *"To establish a food-producing ecosystem that is beneficial for biodiversity and is adapted to climate change and that also stores relatively big amounts of carbon both in the ground and in the biomass"* (F8).

Farmers also explained that silvopastoral systems were adapted to exceptional droughts, such as in 2018, since the vegetation in these agroforestry systems provided better fodder and shade for the animals than grazing systems without trees. Likewise, in forest gardens, due to a planted ground layer and a layer for organic litter, moisture was kept in the soils during droughts.

Landscape stewardship was another motivation for some farmers. The farmers wanted to use traditional knowledge to restore and maintain past agroforestry landscapes (F3, F4). One farmer who had recently initiated forest grazing said, *"This piece of land (the birch forest grazed by sheep) makes our land coherent. It is located between our farm and the lake, making it accessible. It is also a place for us (humans) for hiking and horseback riding. This is good management of the landscape. It is also beautiful"* (F12).

Ecosystem services attributed by farmers to agroforestry systems

Supporting ecosystem services – In this category, the perceived ecosystem services were nutrient cycling and supporting biodiversity (see Fig. 1). Farmers believed that the large roots of the trees recirculated nutrients in the alley cropping system. Many farmers also believed that fodder production simultaneously contributed to biodiversity: *"The goal with our pastures is to find a production system without ploughing. Today, these fields keep a diversity of plants which we want to support"* (F4). Several farms (F2, F4, F10) applied continuous-cover forestry to manage their forests. As one farmer explained, this forest management helped maintain habitats for numerous species and many other functions. The farmer also expressed their appreciation of biodiversity: *"There are many insects; we see new species every day, and also the birdlife is valuable for us, in the future we do not want to keep animals at the cost of wild biodiversity*" (F9).

Provisioning ecosystem services – This category of ecosystem services captured the most diverse set of ecosystem services compared to other categories that farmers attributed to their agroforestry systems (Fig. 1). In total, 12 provisioning services were acknowledged. Various products were produced in the studied agroforestry farms, both for sale and household consumption. Among those products were meat, cereals, eggs, dairy products, fruits and nuts, herbs, mushrooms, fodder, vegetables, wild food, and different assortments of wood and fur. The food products were the most diverse. For example, farms with forest gardens produced a high diversity of perennial crops such as nuts, fruits, berries, perennial vegetables, herbs, flowers and seedlings. The number of species and varieties ranged from 30 to 400. The

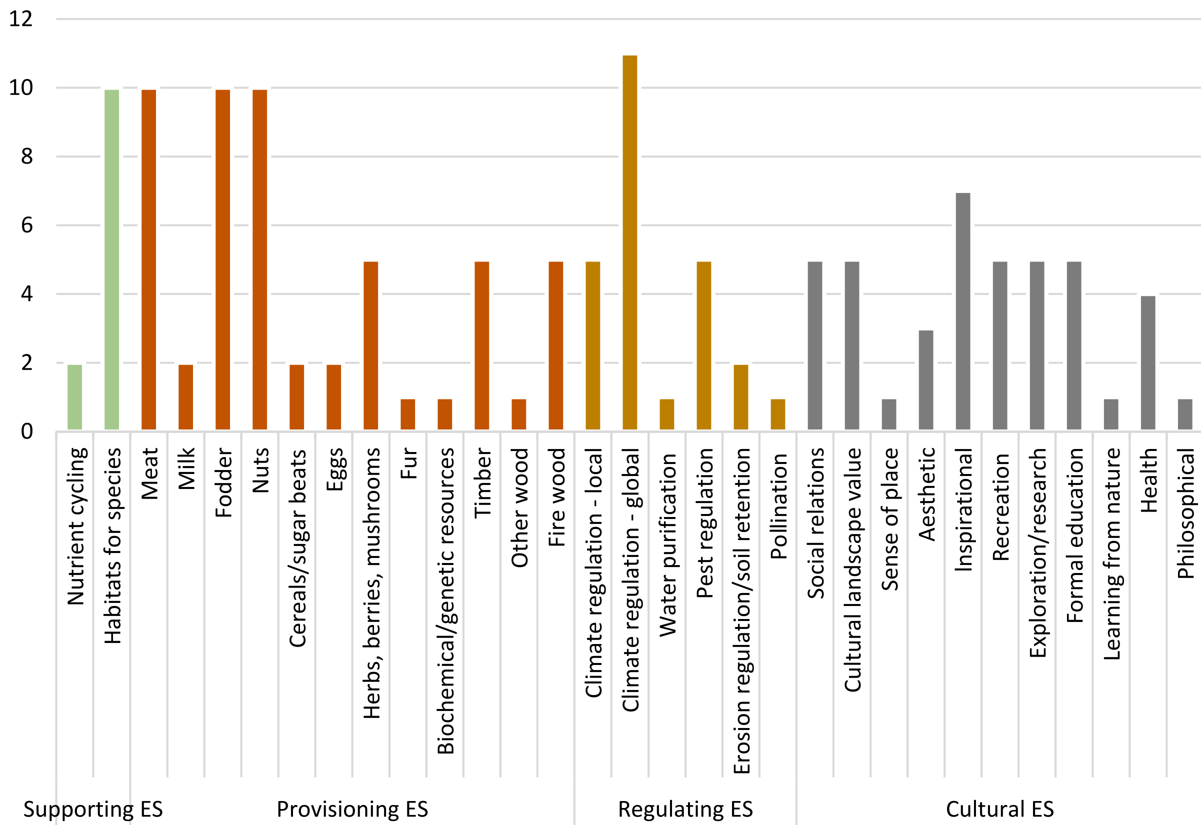

Fig. 1 Ecosystem services attributed by farmers to their agroforestry systems. Numbers show how many farms attributed specific ecosystem service to their agroforestry systems

best-performing crops from farmers' perspectives were hazel nuts (*Corylus avellana*), apples (*Malus Domestica*), and new species of berries for a Swedish context such as sea buckthorn (*Hippophae rhamnoides*), saskatoon (*Amelanchier alnifolia*), aronia (*Aronia melanocarpa*) and Japonese quince (*Chaenomeles japonica*), as well as perennial vegetables. Among the wood products, several farmers produced firewood and one timber from walnut, rowan and cherry.

The supply of many provisioning services was perceived by farmers in combination with the delivery of supporting services. For example, beef production was integrated with the maintenance of biodiversity in the Natura 2000 area (F13). The farmer explained that they kept extensive grazing to maintain patches of semi-natural grassland, wood pasture and forest grazing areas: "The government wants grazing animals to keep the landscape open. This is not about the production of meat primarily, but for nature conservation, landscape care, keep it open" (F13). He also referred to research conducted in the nature reserve, which showed that the growth of trees was better in areas with grazing cows compared to a fenced, non-grazed area on the same land.

Other farmers explained that all agroforestry systems provided food but also contributed to keeping the natural environment which is necessary for health and wellbeing, including physical and psychological experiences (cultural ecosystem services). One farm (F6) provided farm products for lunches for staff and pupils, taught about agroforestry and used their agroforestry farm for wellbeing: *"The school has also focused on good outdoor environments and health, places for rest, calm places and to create…well, environmental psychology. We want to develop a good outdoor environment for the health of everyone working and studying here"* (F6).

Regulating ecosystem services – Farmers perceived that their way of farming contributed to climate regulation, pest regulation, water purification, regulation of soil quality and pollination (Fig. 1). Climate regulation was mentioned by farmers most frequently. Farmers perceived that their agroforestry systems were beneficial due to carbon binding from large root systems of the woody perennials. Additionally, by applying no-digging/tilling techniques and perennial crops, the agroforestry system became more resilient to drought*s.*

The farmers also brought up that their agroforestry systems contributed to pest regulation. As a number of farmers explained, some agroforestry systems were affected by pests (often by voles), but the pests were reduced by special modifications of the agroforestry systems. For example, farmers kept hens to protect fruit trees from voles, or added poles suitable for predating birds. *"On the poles, the predating birds sit, meaning this land (the alley cropping) has become beneficial for wildlife"* (F11). On other farms, insects have been observed, which were perceived to contribute to pollination. "Pollinating insects have been observed from early spring until late fall" (F1). Finally, the farmers dealt with eutrophication caused by leakage of nutrients from arable land by practising alley cropping on the fields, in which cereals and rows of fruits and berries were produced: *"Woody plants with deep roots could probably contribute to absorbing the nutrients since the root system of the perennials are there all year"* (F1).

Cultural ecosystem services – The farmers attributed multiple cultural ecosystem services to their agroforestry farms (see Fig. 1). The exploration of agroforestry systems was extensive and multifaceted. It included testing new species and varieties. For example, several farmers (F6, F8 and F10) tested around 400 species/varieties. Farmers explored the productivity, taste and adaptation to Northern climatic conditions of different species and the establishment of whole systems such as forest gardens, silvoarable systems or forest farming. "We test wide varieties of crops; they end up in our market garden. We do a lot of research and development work. We also test several methods to establish a forest garden and get it 'self-managed'" (F10). Learning from experiments with forest farming in mixed forests generated new cultivation practices, such as growing mushrooms on logs, and knowledge needed to provided multiple benefits, such as the conservation of the forest habitats and species, the storage of carbon and the provisioning of wood for various purposes. The restoration of traditional pastures to increase biodiversity also generated wellbeing for the farmers through furthering aesthetic qualities: *"We keep mountain-dwelling cows, sheep (for fur) and hens. We had them for a long time because we want to open up and restore these pastures, just because we like them, they are nice, they are beautiful"* (F4).

With regard to education and knowledge, farmers arranged short-term workshops or courses (on weekends) and were also engaged in relatively long-term formal learning programmes (6 months) with local folk high schools (F2, F6 and F10), in which their agroforestry systems were central or partly used in pedagogy. Knowledge was considered the main "product" for F10: *"Many people want to learn about this way of production because it is beneficial for the environment" (F10).* Several farms had extensive activities for knowledge sharing. F1 had a demonstration site for farmers with 140 perennial crops suitable for the arable field adjacent to the alley cropping test field. The agroforestry systems were often used for informal and formal learning. As one farmer explained, this was done "to create an educational environment for children and adults where one gets inspiration and can learn about ecology, forest gardens, food production and gardening" (F8).

Some farms were involved as partners in formal research ventures. Several farms let other researchers use their land (F1, F4, F6 and F13). Six farms (F1–F6) were partners in a participatory action research (PAR) project for four years (Björklund et al. 2018; Schaffer et al. 2019). F11 was a university test site for silvoarable systems. Some farms conducted own investigations and documentation, such as an inventory of biodiversity at F7. F10 produced reports about certain aspects of its agroforestry systems, such as water and nitrogen balances and the nutrients and toxic content of the crops. F1 had been a partner in several research and development projects on climate adaptation and carbon binding for farms in Northern climates.

Farmers also provided conditions for recreational activities: "The aim with our home garden, the forest garden, is to generate as much harvest as possible with as little work as possible and to create a place for recovering, restoration… (F10). Or another example, "…now the focus is to create a fantastic place for us, for visitors. Today having a rich biodiversity is more important than selling" (F9). Five farms (F2, F4, F6, F8, F10) had cafés and cottages for rental, or to host various events they organised. Some offered guided tours in which the agroforestry system was included. F5 ran an on-farm restaurant where visitors often spent time in the garden with a mosaic of trees and annual and perennial crops. In this way, "non-farmers" could see and learn about an "unusual" production system. "I live to inspire others, and since we are located in [an area for] extreme commercial tourism, we offer other things. Visitors can see recycling, close loop models in practice" (F5).

Farmers appreciated the biocultural heritage inhering in wooded pastures which provided habitats for certain species due to traditional silvopastoral practices (cultural heritage). *"In the wood pastures, there are roses, sloan, juniper, gooseberries, wild strawberries, chanterelles, oak, cherry, rowan* etc., all of which historically must have been important for livelihood for the farm. Birch for firewood is still harvested…some visiting experts perceived this landscape should be kept since it had been intentionally created" (F3).

Perceived challenges in practising agroforestry

Agroforestry farmers also explained the challenges they faced in their agroforestry practices, which we organised into four broad groups.

The first group was related to challenges in the management of agroforestry farms. For example, the high diversity of species in the forest gardens was perceived as too complex to get a proper quantity of products. *"My attitude towards forest gardens was always negative because we need large quantities of products (for our restaurant). Therefore, we also plant vegetables in rows"* (F5). There were also practical hindrances such as pests (voles). The problems with voles and the complexity of agroforestry systems were solved by decreasing the number of species and keeping hens. *"We have problems with voles, and therefore we have to keep the hens in the garden, and we don't have a planted ground layer but instead trees, shrubs and hens"* (F5).

The second group was related to a lack of technologies suitable for small-scale agroforestry farms and a lack of supplies. *"Technology and machines for small-scale users would be needed, such as two-wheel tractors, for making wood chips or rotary cultivation, there are no such machines in Sweden"* (F6).

The third group was related to lack of plant materials, including seedlings, which was crucial for scaling up agroforestry production. For example, several new species of edible perennials were popular, but the lack of seedlings was perceived as a limitation for the expansion of this type of agroforestry system: *"The supply of varieties of plants is a limitation (in Sweden). For example, everybody thinks Japonese quince is a fantastic, beautiful and useful fruit instead of citrus, but it is impossible to find seedlings here"* (F6). The farmers used their land as test sites to support research on production of seedlings, but they complained that the progression from a research site to production took a very long time: *"We cultivate for a test site for the university. Normally they do research on breeds, varieties and how to make the seedlings reach the market. It is a very long process through the value chain: the buyer must demand them, the stores must be willing to have a supply of them, and the farm and the market gardens need to cultivate the seedlings. This system, the long process, is a limitation for more farms to dare to test new varieties for seedlings on as much as several hectares"* (F6).

The fourth group of challenges was the lack of knowledge on establishing agroforestry on new land and maintaining it: *"We do experiments with grazing and forestry. The reforestation is a challenge"* (F2). There was both curiosity and doubt regarding scaling up agroforestry: *"[I] would like to explore the management of a whole agroforestry system. And agroforestry in a larger scale, what would that look like?"* (F5).

Discussion

Diversity of agroforestry systems in Sweden

This study addresses several knowledge gaps related to agroforestry systems in Northern Europe. We explored the perceived benefits attributed by farmers to diverse agroforestry practices within four distinct systems—silvopasture, silvoarable, forest farming, and forest gardens—in Sweden. Scholars have presented evidence that silvopastoral and silvoarable systems have the potential to enhance biodiversity, improve soil fertility, reduce erosion, enhance water quality, increase aesthetics, sequester carbon, and offer opportunities for recreation and tourism across various spatial and temporal scales (Jose 2009; Martín-López et al. 2012; Oteros-Rozas et al. 2014; Torralba et al. 2016; Burgess and Rosati 2018; Smith et al. 2022). Our study also supports these findings; however, we identified also perceived benefits attributed to forest gardens and forest farming—agroforestry systems, which have not been previously documented in Europe, including Sweden (Mosquera-Losada et al. 2018a, b). For example, our study documented that farmer attributed the production of 17 ecosystem services to forest gardens, spanning all four established categories—supporting, provisioning, regulating, and cultural.

Another finding is that farmers incorporated multiple agroforestry systems on their farms. Specifically, two farms implemented three agroforestry systems—silvopasture, silvoarable, and forest garden/or forest farming, while five farms integrated two agroforestry systems (Appendix 1). We argue that combining different agroforestry systems within a single farm is a dynamic and innovative approach that reflects the adaptability of agroforestry practices to create a more resilient and diverse agricultural landscape. One advantage of combining different agroforestry systems is the optimization of land use. Each system contributes unique benefits—silvopasture integrates livestock grazing with trees, silvoarable combines trees with annual crops, and forest gardens foster a diverse range of perennial plants. By incorporating these systems, farmers can make efficient use of space and resources, enhancing overall productivity. From an economic perspective, diversifying agroforestry systems within a farm can lead to multiple income streams. Farmers can harvest timber, fruits, nuts, and other products from various components of the agroforestry landscape. This diversification not only enhances the resilience of the farm against market fluctuations but also provides a more or less steady income throughout the year.

Additionally, we recorded multiple perceived cultural ecosystem services attributed to all studied agroforestry systems. In total, farmers associated 11 different cultural ecosystem services with their agroforestry systems—a category that has been under-researched until now (Fagerholm et al. 2016; Torralba et al. 2016; Sollen-Norrlin et al. 2020).

Farmers as designers of multifunctional agroforestry farms in Sweden?

One of the main findings of this study is that the multifunctionality of all studied agroforestry systems arises from farmers' motivation to design such systems. The farmers were driven by the desire to be designers of multifunctional landscapes, and they consistently merged their intentions to derive food and materials from their farms with the deliberate pursuit of multiple ecosystem services, driven by both motivation and necessity. In the context of initiating agroforestry practices in Sweden, farmers were motivated by four broad groups of factors—sustaining one's household economy, supporting environmental sustainability, adapting and mitigating climate change, and providing landscape stewardship. Existing literature demonstrates similar motivations among agroforestry farmers across Western Europe (Graves et al. 2009; García de Jalón et al. 2018; Hernandez-Morcillo et al. 2018; Rois-Diaz et al. 2018; Sandberg and Jakobsson 2018; Johansson et al. 2022). All interviewed farmers expressed a concern for the natural environment and recognised the cultural value of the landscape. They envisioned agroforestry as a platform for introducing new ideas and practices to mitigate the negative impact of farming on the environment while sustaining the cultural value of the landscape.

Biodiversity conservation, carbon storage, soil quality and resilience to extreme weather conditions were identified as primary environmental concerns that farmers sought to address through diverse management strategies on their agroforestry farms. Farmers also perceived agroforestry as a solution for maintaining the aesthetic qualities and the cultural value of landscapes which their ancestors created. Thus, farmers perceived their role not only as food producers, which is traditionally the primary goal of farmers, but also as landscape stewards. The goal was not to reach maximum profitability but to find a balance between economic, environmental and cultural farm outputs. Albrecht and Wiek (2021) assessed the sustainability benefits of forest gardens in Europe, North America and South America, and concluded that they performed better environmentally, culturally and socially, but were weaker in relation to profitability, which is in line with our findings.

Regarding which kinds of service contributions were seen as most necessary, we can say that multiple cultural ecosystem services such as social relations, education and knowledge, recreation and tourism were crucial to getting a sustainable supply of provisioning services. For example, learning from each other was essential for farmers to generate new knowledge and deal with challenges in practising agroforestry. Providing opportunities for events such as education and tourism were vital to sustaining the economy of agroforestry farms. Supporting soil quality and regulation of pollination were crucial for the sustainable supply of provisioning services.

Our results enable us to identify key factors influencing farmers' decisions to practise agroforestry. Over the last few decades, scholars have delved into the behavioral factors shaping farmers' decisions to adopt environmentally sustainable practices, including agroforestry. In their review of such studies, Dessart et al. (2019) proposed three types of behavioral factors impacting farmers' decision-making: dispositional factors, related to the personal qualities and values of farmers; social factors, encompassing social interactions with other individuals, including social norms and motives; and cognitive factors, involving farmers' perceptions of the relative benefits, costs, and risks associated with a particular sustainable practice. Our study demonstrates that all three types of factors influenced farmers' behavior in practising agroforestry; importantly, these factors acted simultaneously.

Farmers had environmental concerns, practised long-term strategic thinking and were open to new experience (dispositional factors) on sustaining their household economy through diversification of farm products and services. For example, they introduced extensive farm management to reduce management costs and labour, as well as to diversify and maintain household income while reducing the negative impact of their activity on the natural environment. The combination of farming with educational courses, guided tours, and small-scale businesses (e.g. cafés) is another example of strategies pursued (linked to social and cognitive factors). These activities generated income and promoted environmental awareness to develop new food and wood production methods in line with sustainable development principles.

Other scholars (Wilson and Lovell 2016; Sollen-Norrlin et al. 2020) also have showed that diversification of income from products and services is essential for sustaining agroforestry farms. For example, mushroom cultivation on logs combined with forestry could contribute to income in the short-term and the long-term. Similarly, the farmers in our study were innovative (dispositonal factors) to begin practising agroforestry from scratch. They had to decide what type of agroforestry to choose, how to integrate different agroforestry practices in space and time, etc. All farmers were keen to learn continuously from other farmers and from collaboration with researchers to test new management options to improve land management which would be less harmful for the natural environment (cognitive factors). This learning was essential to generate new innovative agroforestry practices so as to maintain complex spatial and temporal arrangements of crops, trees and animals on different types of land: forested land (e.g. forest farming), predominantly forested land with some agricultural use (e.g. forest grazing), or agricultural land with the introduction of trees (e.g. alley cropping). We posit that the sustained adoption of agroforestry practices over a relatively extended period of time has resulted from the cumulative impact of dispositional, social, and cognitive factors. This resilience allowed farmers to persist in agroforestry despite facing multiple challenges.

Our study shows that each farmer deliberately organised farming activities to get a bundle of ecosystem services produced belonging to four categories—provisioning, regulating, supporting and cultural. In this study, we understand ecosystem service bundles as "sets of ecosystem services that repeatedly appear together across space or time" (Raudsepp-Hearne et al. 2010), being positively (synergy) or negatively (trade-off) associated with each other (Mouchet et al. 2014). The delivery of ecosystem service bundles resulted from the diversification of forestry and agriculture at the farm level. Agricultural measures undertaken included, for example, the diversification of silvopasture systems through the integration of crops with livestock, diversification of crops, and the implementation of multilayer systems of perennial and annual plants, creating structural elements in the fields (e.g. alleys). Diversification forestry measures involved applying continuous-cover forestry, maintaining the diversity of deciduous tree species and preserving the multilayer structure of forests.

Recently, issues of synergies, trade-offs and bundles have gained the attention of scholars to better understand how to manage multiple ecosystem services across landscapes (Rodriguez et al. 2006; Raudsepp-Hearne et al. 2010; Plieninger et al. 2015; Eak et al. 2016; Hanes et al. 2017). Scholars argue that applying the ecosystem service bundles approach could be a helpful tool in identifying landscapes with different degrees of multifunctionality and in analysing direct and indirect drivers that underpin synergies and trade-offs among ecosystem services (Saidi and Spray 2018). Our study shows that from the farmers' perspectives, their agroforestry systems support synergies among provisioning, regulating, supporting and cultural ecosystem services. At the same time, farmers realised that by enhancing regulating and supporting ecosystem services, they might reduce quantity in the production of food, fodder, timber or other provisioning services. Farmers lowered costs by reducing labour input and machinery to handle such trade-offs. Other scholars (Decocq et al. 2016; Burton et al. 2018; Hardaker et al. 2021) show that the integration of trees and woodlots within agricultural landscapes as land-sharing measures supports the delivery of a wide range of in-situ (e.g., food production) and ex-situ (e.g., carbon sequestration and flood mitigation) ecosystem services. In their review of studies on diversified farming systems, Rosa-Schleich et al. (2019) concluded that diversified farming systems, including agroforestry systems, offer significantly greater benefits for biodiversity and associated ecosystem services compared to conventional agriculture. However, the ecological advantages for farmers were partially insufficient to outweigh economic costs in the short term, despite numerous examples illustrating that diversified practices led to higher and more stable yields, and reduced risks in the long term. We argue that further research is needed to explore synergies and trade-offs of ecosystems services generated by different agroforestry practices in diverse biophysical, cultural and socio-economic contexts, to better understand the extent to which agroforestry contributes to landscape multifunctionality at different spatial and temporal levels. Our study also raises the question of whether development and mindful inclusion of agroforestry modes of production at the farm scale could contribute to a mosaic at the landscape scale that even may transcend the land-sharing/land-sparing dispute. Might such a strategy result in multifunctional landscapes with areas of intensive production combined with agroforestry, where supporting and regulating ecosystems services, conservation and landscape connectivity is assured, resolving or at least addressing the trade-off between complexity and quantity?

Another issue that our study highlights is that people-nature interactions are a core characteristic of agroforestry systems which are the product of a delicate balance of multiple human activities, transforming ecosystems. Thus, the multiple tangible and intangible benefits derived from agroforestry should be considered as "social-ecological services" rather than ecosystem services (Elbakidze et al. 2021; Huntsinger and Oviedo 2014). Furthermore, some of these services are only apparent at the landscape scale, where patches with different densities and structures of land cover types are combined. Consequently, some have suggested a transition towards "landscape services" for the planning and management of ecosystems of cultural nature (Termorshuizen and Opdam 2009). Additionally, our study shows that farmers attributed multiple values to their agroforestry farms. which are increasingly acknowledged as a key research priority for agroforestry systems' sustainable governance and management (Arias-Arévalo et al. 2017; Plieninger et al. 2013). Gaining a better understanding of such values is an essential step to better disentangling the societal relevance of agroforestry systems under different biophysical, social-cultural, economic, and governance conditions (Fagerholm et al. 2016; Plieninger et al. 2015).

Recently, the nature's contributions to people (NCP) analytical paradigm and the multiple-value approach (Díaz et al. 2018; Pascual et al. 2017) have been introduced in the conceptual framework of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). The NCP approach recognises the central role that culture and local knowledge play in defining all links between people and nature (Díaz et al. 2018), while the multiple-value approach acknowledges culturally different worldviews, visions, and strategies to achieve an improved quality of life by considering a widened rage of nature-related values, including the values attributed and perceived by indigenous people and local communities (IPBES 2019). Elbakidze et al. (2021), in their study applying the multiple-value approach, provides strong evidence that agroforestry systems in north-eastern Europe contribute multiple benefits important for people's quality of life and show that relational values were attributed to agroforestry systems by the majority of respondents across all contexts. We argue that more studies applying different methods and approaches are needed to capture the complexity of agroforestry systems, including the multiple benefits they provide and the diversity of values attributed to these systems by various stakeholders (including farmers). Such studies will contribute to a higher recognition of agroforestry systems in policy and planning decisions and underpin more sustainable management strategies and pathways.

Perceived challenges

We grouped challenges that farmers experienced in practising agroforestry into four groups, such as complexity of agroforestry management, lack of technologies suitable for small-scale agroforestry farms, lack of plant materials (including seedlings), and lack of knowledge about how to do agroforestry. These findings are in line with the challenges identified among agroforestry farmers in Europe. For example, the study by Garcia de Jalon et al. (2018) that involves four types of agroforestry across Europe, as well as the study by Graves et al. (2009), showed that farmers perceived similar challenges regarding silvoarable systems, such as lack of farm machinery and increased work complexity but also feasibility.

However, several of our findings contradict the results of other studies. For example, one common challenge which is often brought up regarding adopting agroforestry relates to high initial costs (Garcia de Jalon et al. 2018; Sollen-Norrlin et al. 2020). Our study shows that the farmers did not address financial constraints as a challenge. One potential explanation for this could be that at least 11 out of 13 farmers could be seen as agroforestry pioneers. Despite the lack of financial support, they were highly motivated to test new sustainable practices. However, if more farmers would follow this path, more financial support might be needed (among other things). Smith et al. (2022) show that agroforestry may have greater financial margins than traditional systems due to the diversification of practices and activities such as, for example, combining the production of various products with on-farm courses and workshops.

Another common challenge addressed in other studies, for example in Sollen-Norrlin et al. (2020), is that "agroforestry is unknown", but this was not a major concern among the farmers in our study. One potential explanation for this could be that many of these farmers met a lot of people on their sites that visited the farm in order to learn more about agroforestry.

Development implications of agroforestry in Sweden

Considering the multiple benefits attributed by farmers to diverse agroforestry systems, we argue that agroforestry farms could be seen as hubs of rural development in Sweden. Sweden's rural areas play a vital role in the country's development. Beyond their economic contribution, rural landscapes offer crucial living environments, supply a diverse range of cultural ecosystem services (Garrido et al. 2017a, b), and are essential for supporting nations' biodiversity (Gustavsson et al. 2007). However, rural areas face long-term challenges, including a significant reduction in the number of active agricultural and forestry enterprises, with over 66% of the remaining small-scale farm enterprises relying on off-farm incomes (Swedish Board of Agriculture 2017) and the loss of human and social capital. This has resulted in a demographic imbalance, with fewer younger people and women in rural areas, alongside the erosion of trust, traditional relationships and identities associated with rural landscapes. Moreover, climate change has emerged as a significant driver of change in rural production (Grusson et al. 2021). Our study shows that agroforestry farms and farmers provide multiple cultural ecosystem services that could contribute to maintaining social and human capital, cultural identity and rural landscape value, which are needed to sustain and maintain rural areas as attractive living environments. Regarding climate change, our study and also other scholars show that agroforestry systems help to adapt to and mitigate climate change. More importantly, considering that farmers engage in continuous learning, we might argue that they would learn how to adapt production to new climate conditions through pursuing agroforestry.

The challenges in rural development are not unique to Sweden but are common across Europe, despite substantial investments in rural areas through the CAP (EU 2016). Various policy initiatives have been developed at both the EU and national levels to address these challenges. A central component of these initiatives is the promotion of entrepreneurship and innovation in agriculture and forestry. The aim is to create new employment opportunities, sustain commercial and public services, and make rural areas attractive places to live and work. In this context, agroforestry systems might contribute to the development of new and more sustainable ways of production, as well as producing high-quality products, leading to the diversification of household income in rural development, sustaining human and cultural capital as well as landscape value.

Regarding policy implications, Plieninger et al. (2020) argue that the UN Sustainability Development Goals (SDGs) can be concretised through agroforestry. Agroforestry could also contribute to the implementation of several European-level initiatives such as the Pan-European Biodiversity and Landscape Strategy, and the European Landscape Strategy (Forest Europe 2018). For farmers in the EU member states, the CAP is crucial. Scholars argue that agroforestry could fulfill what CAP aims to a much larger extent than what has been done so far (Mosquera-Losada et al. 2018b, 2023; Santiago-Freijanes et al. 2021). However, the existing policy tools to enhance and support agroforestry systems remain inefficient. One indicator supporting this statement is the sharp decline of agroforestry systems across the EU (Eichhorn et al. 2006; Plieninger et al. 2015; Almeida et al. 2016; Godinho et al. 2016). Our study underscores the pivotal role of farmers as the architects of agroforestry systems. Drawing on Deaasart et al. (2019), we argue that understanding farmers' behavior and integrating behavioral factors into agri-environmental policies might lead to more effective and realistic policy outcomes supporting the development of agroforestry systems.

Limitations of the study

The selected farmers met the criteria outlined in this study (see Methods); however, it is worth noting that a significant proportion of these farmers were well-educated, actively participated in various projects, owned land, and generated additional income. Consequently, our sample primarily represents a specific subgroup of farmers, and caution should be exercised when generalizing our findings. Furthermore, our primary emphasis was on exploring farmers' motivations, perceived benefits, and challenges associated with practicing agroforestry in Sweden. Consequently, we did not delve extensively into the specific business models adopted by farmers. Nevertheless, as this aspect emerged during our study, we were able to provide an overview of the business models, albeit without exhaustive details.

Conclusions

Many studies indicate that agroforestry systems offer multiple benefits crucial for biodiversity and human well-being. However, there exists a significant gap in studies on agroforestry systems in North Europe, including Sweden. This study addresses this gap by documenting the perceived benefits attributed by farmers to diverse agroforestry practices within silvopasture, silvoarable, forest farming, and forest gardens in Sweden. The two latter systems were documented in relation to this perspective in Europe for the first time.

This study shows that the multifunctionality of studied agroforestry systems are the result of farmers' multiple motivations to practise agroforestry, such as generating income, supporting environmental sustainability, mitigating and adapting to climate change, and being a landscape steward. Each farmer deliberately organised their farming activities to produce a bundle of ecosystem services belonging to provisioning, regulating, supporting and cultural services. In pursuing such action, agroforestry farmers make use of special personal qualities, such as long-term strategic thinking on sustaining their household economy through diversification of farm products and services, and being innovative in dealing with multiple challenges related to practising agroforestry. Key behavioral factors influencing farmers' decisions include dispositional, social, and cognitive factors. Additionally, farmers incorporate multiple agroforestry systems on their farms, optimizing land use, making efficient use of space and resources, enhancing overall productivity, and diversifying income streams to increase farm resilience against market fluctuations, providing a relatively steady income throughout the year. However, farmers experienced challenges in practicing agroforestry, such as the complexity of agroforestry management, a lack of technologies suitable for small-scale agroforestry farms, a shortage of plant materials, and a lack of knowledge about how to implement agroforestry. More studies are needed to explore the diversity of business models applied by farmers belonging to different groups based on factors such as age, experience, and financial conditions. These studies should be conducted in different contexts, considering the various agroforestry systems in practice.

Considering the multiple benefits attributed by farmers to diverse agroforestry systems, we argue that agroforestry farms could be seen as hubs of rural development in Sweden. We argue that understanding farmers' behavior and integrating behavioral factors into agri-environmental policies might lead to more effective and realistic policy outcomes on the ground. Additionally, more studies employing different methods and approaches are needed to capture the complexity of agroforestry systems, including the multiple benefits they provide and the diversity of values attributed to these systems by various stakeholders, including farmers. Such studies will contribute to a higher recognition of agroforestry systems in policy and planning decisions, supporting more sustainable management strategies and pathways.

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection and initial analysis were performed by CS. The first draft of the manuscript was written by CS. ME and JB read, edited and commented on the paper throughout. All authors read and approved the final manuscript.

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Declarations

Conflict of interest No conflict of interest.

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