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Policy challenges for agroforestry implementation in Europe

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Agroforestry (AF) is a sustainable land use practice and system that increases the ecosystem services delivery from agricultural lands compared with treeless systems. Agroforestry can be considered a practice when linked to plot scale (silvoarable, silvopasture, homegarden, woody linear landscape strips, and forest farming), and a system when associated with the global farm scale. The enhancement of the ecosystem services is associated with the use and promotion of the biodiversity caused by the presence of trees that optimizes the use of the resources if adequate species are mixed. Agroforestry can be implemented at temporal and spatial scales. At the temporal scale, the use of woody perennials to increase soil fertility is a traditional technique that improves soil health and reduces the need of using herbicides (e.g., the legume *Ulex* sown for 10 years in between crop cultivation). Five agroforestry practices can be implemented at the plot level: silvopasture, silvoarable/alley cropping, homegardens/kitchengardens, woody linear landscape strips, and forest farming. A farm including these practices is considered an agroforestry system working at the landscape level when several farms are mixed. In spite of the acknowledgment that AF has at the European level for being included as part of Pillars I and II, the spread of AF is limited across Europe. Four challenges, linked with technical, economic, educational, and policy development, have been identified by the AFINET thematic network that, if addressed, may foster policy adoption across the EU. This article proposes 15 different policy recommendations to overcome them and the need of developing an AF strategy for the EU.

KEYWORDS
agroforestry definition, agroforestry practices, biodiversity, ecosystem services, agroforestry adoption

1. Introduction

Europe faces the important challenge of establishing sustainable agriculture and implementing food security (Mosquera-Losada et al., 2012) while reducing negative impacts on the environment, including biodiversity loss and climate change, as declared by the Green Deal [European Union (EU), 2020a] and the Farm to Fork strategy [European Union (EU), 2020b]. Climate-smart agriculture (CSA) contributes to the achievement of global sustainable development goals [Food and Agriculture Organisation (FAO), 2022] as it integrates the three dimensions of sustainable development (economic, social, and environmental) by jointly addressing food security and climate challenges. The CSA document published by the Food and Agriculture Organisation (FAO) (2022) includes agroforestry (AF) practices as part of integrated systems to promote within the CSA framework, as was included by the European Union (Decision 529/2013/EU). The huge potential contribution of AF to CSA is linked with the possibility of being applied at the plot, farm, and/or landscape levels, depending on the spatial use and combination of agroforestry practices. In fact, the environmental impact of intensive agriculture has become increasingly negatively acknowledged [Food and Agriculture Organisation (FAO), 2022]. In this regard, modern agriculture has to combine high productivity with low impact in order to feed sustainably the growing world population, that is to say, an eco-intensification of agriculture should take place [European Union (EU), 2020a]. AF has been recognized as a sustainable land use practice and system, mixing modern and traditional practices, that is not currently acknowledged by farmers or policymakers. Therefore, the expansion of AF in Europe should consider both the main challenges highlighted by farmers to adopt AF practices and the promotion of an enabling environment (policies, funds, support, and infrastructure) from policymakers as found in the AFINET project. In the European Union, the Common Agriculture Policy (CAP) is one of the most relevant drivers for the agricultural sector, which should be used to promote AF adoption in the European continent. For the purpose of this study, agroforestry can be considered a practice when linked to plot scale (silvoarable, silvopasture, homegarden, woody linear landscape strips, and forest farming), and a system when associated with the farm scale and at the landscape level when several farms are combined. This study aims at describing the main AF practices in Europe and identifying the main challenges to AF adoption as a land management use and proposes a set of solutions from a policy perspective to favor an adequate business environment for farmers from the CAP.

2. Agroforestry: Biodiversity and ecosystem services delivery in Europe

Agroforestry (AF) is a sustainable land use practice and system recognized by the Food and Agriculture Organisation (FAO), 2015, which provides many ecosystem services and can increase sustainability in the different types of agricultural land use recognized by the CAP: arable lands, permanent grasslands, and permanent crops (woody perennials and fruit trees), as shown in Figure 1. Farmers together with policymakers and consumers are key actors to foster the implementation of AF; therefore, they should be informed (and participate in discussion forums) about the sustainability that AF provides.

2.1. Biodiversity

Regarding the important role of AF on biodiversity, several reports have been published (Rois-Díaz et al., 2006) as well as several books and book chapters and papers on the role of AF in the adaptation and mitigation of climate change in agricultural systems (Mosquera-Losada et al., 2005, 2018b; Nair et al., 2009; Rigueiro-Rodríguez et al., 2009; Howlett et al., 2011a,b; Mosquera-Losada and Prabhu, 2019; Santos et al., 2022).

From a **biodiversity** point of view, the increase in productivity per unit of land is based on biodiversity, which allows improved efficiency in the use of the resources (radiation, water, nutrients, etc.) as found by McAdam et al. (2009). The presence of a tree in a treeless land causes disturbances and generates microclimates within the treeless/tree plots (Rigueiro-Rodríguez et al., 2012). In fact, the tree/shrub modifies the main ecological factors (radiation, temperature, and humidity), creating microhabitats for different species that differ from those growing up in open areas, therefore, increasing biodiversity per unit of land (McAdam et al., 2009; Santos et al., 2022). The presence of animals also enhances AF due to the impact of different animals on different plant species selected, trampling, and feces (Rigueiro-Rodríguez et al., 2012). In addition, AF practices have also been impacted at a landscape level, which is used to improve crop production (Mosquera-Losada and Prabhu, 2019). This is the case of many eastern countries, such as Bulgaria or Hungary, which planted many forest belts, hedges, and hedgerows in the past to reduce the impacts of climatic factors (e.g., wind), therefore, creating microhabitats for many invertebrate species (Takáczs and Frank, 2009; Kachova et al., 2018). Actually, the use of woody vegetation and AF has been highlighted in the first report of the European Commission in the EU biodiversity strategy 2030 (European Union (EU), 2021), where the important role of woody vegetation on pollination has been described (Santiago-Freijanes et al., 2018b).

2.2. Ecosystem services

Agroforestry **(AF) biomass production** is generally higher than that linked to monocrops, when both the crop and the woody perennial production are considered. Finding uses for both components (woody perennial and agricultural components in the understory) are essential to foster AF expansion in the EU. The advantages of AF production are based on the increased biodiversity (by comparison with polycultural and monocultural systems), which allows multipurpose use of land and optimize the use of the resources (radiation, temperature, water, and nutrients), if adequate components (tree/shrubs/crops/animals) are integrated and adequately managed by considering the positive interactions among them (Mosquera-Losada et al., 2016; Santos et al., 2022). Moreover, the woody perennials promote microhabitat

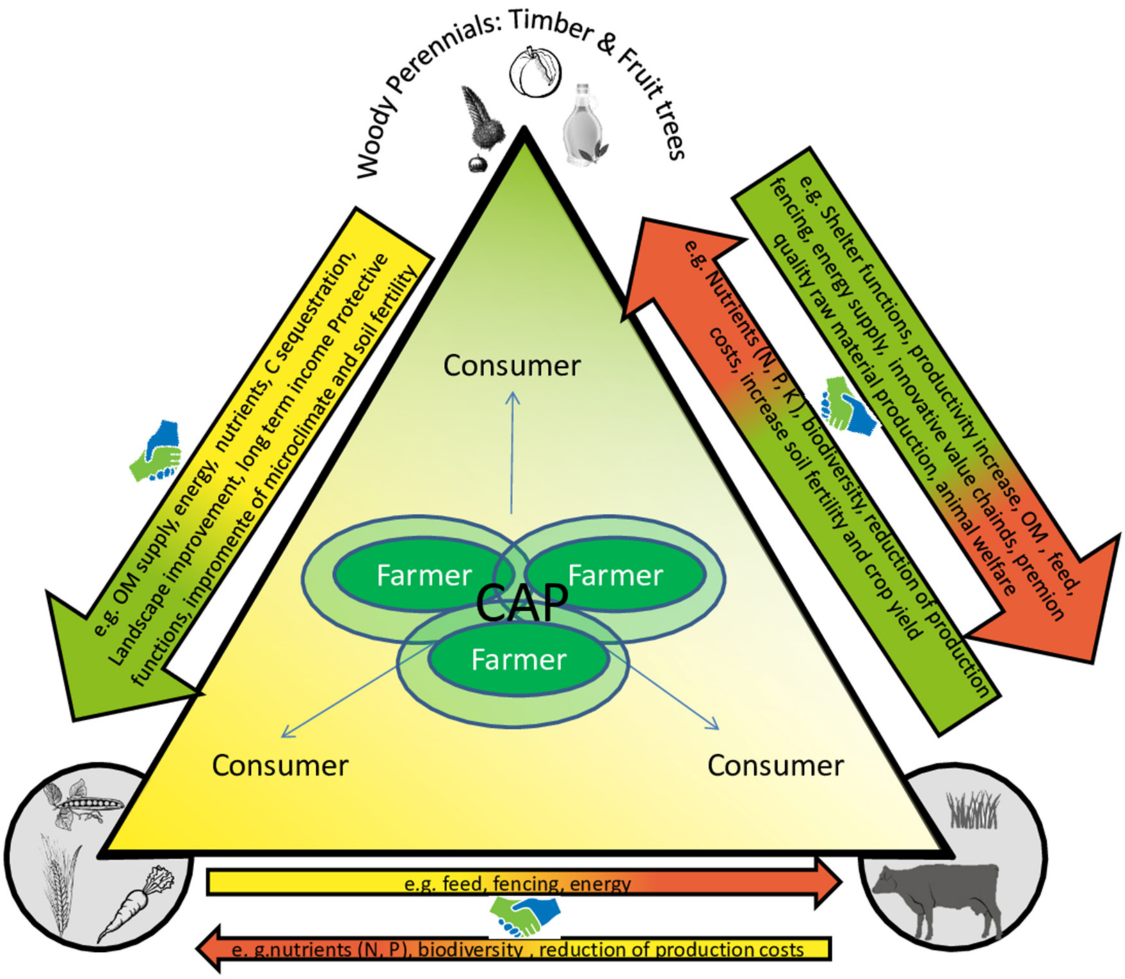

FIGURE 1
Main components and AF benefits for arable, permanent grassland, and permanent crop lands paid by the EU direct payments. OM, organic matter.

connectivity at the landscape level to support biodiversity. The main productive advantages for the producers of the selected tree species and crop varieties are the improvements in the farm's economic balance as the understory is used to generate farmers' income and to avoid understory maintenance (Mosquera-Losada et al., 2016). Moreover, the optimization of the use of the resources generates an increase in biomass production and therefore causes a sustainable way of land intensification. The land equivalent ratio (LER) indicator reveals that 1 ha of AF is equivalent to 1.4 ha of crop+forestry biomass production when they are grown separately (Dupraz and Liagre, 2004).

From a **climate change** point of view, the promotion of woody vegetation is essential for both mitigation and adaptation (Mosquera-Losada et al., 2017). However, it has to be considered that climate change may have an important impact on already existing agroforestry systems such as those linked with the dehesa, trees, and shrubs dying due to climate change. AF has been demonstrated to be useful in reducing the risk of GHG emissions related to fire when the "understory fuel" is consumed by animals (Damianidis et al., 2021). Concerning mitigation, AF has an enormous capacity of increasing carbon (C) sequestration in agronomic and forestland, while avoiding or counteracting emissions and the effects of catastrophic events mostly due to the increase of resilience. In terms of adaptation, there is fragmented information where AF practices have demonstrated to be able to reduce temperature variation by (a) the shade the trees cause, (b) the reduction of wind speed that tree barriers cause to surrounding croplands, and (c) the reduction of the effects of catastrophic events such as flooding (due to the reduction of the impact of heavy rainfall on soil and the better soil structure that the root of the trees provide which enhances water infiltration and reduces runoff) on crop production (Palma et al., 2018; Mosquera-Losada and Prabhu, 2019). Moreover, several researchers have estimated the capacity of AF to mitigate climate change, by counteracting the emissions at the farm scale, due to carbon (C) sequestration in the subsoil (Howlett et al., 2011b). In addition, trees are able to maintain temperature during the hot waves, which reduces the exchange of greenhouse gases (GHGs) with the atmosphere (Rigueiro-Rodríguez et al., 2009). In order to tackle these mitigation and adaptation issues, AF modeling is considered essential, since the yields of trees cannot be directly determined within the duration of a short-term project. SAFE models are based on the development of a range of biophysical models to describe tree–crop interactions over longer time periods, like those described for *Pinus radiata* by Ferreiro-Domínguez et al. (2022a,b,c). The Yield-SAFE model is a parameter-spare model (Van der Werf et al., 2007) for agroforestry practices, mainly dealing with silvoarable or alley cropping. The outputs from the Yield-SAFE model were also used to inform bioeconomic models, such as Farm-SAFE, by comparing the financial and economic benefits of silvoarable agroforestry in relation to monoculture arable or forestry systems (Graves et al., 2011).

3. European agroforestry practices typology

Mosquera-Losada et al. (2018b) identified AF as a set of practices in which woody vegetation, either trees or shrubs, is grown in combination with agriculture on the same unit of land [Food and Agriculture Organisation (FAO), 2015]. This definition is highly relevant as it includes AF practices associated not only with trees but also with livestock production, more adapted to Southern Europe's drier areas. In fact, AF has two main components (woody and herbaceous vegetation) which could be enlarged to a third component, livestock, if silvopasture is practiced (Mosquera et al., 2009). Human is the fourth component or actor who artificially modifies the relationship between the former components, depending on the main agricultural or forest product pursued by the AF system and agroecological conditions (Mosquera et al., 2009). AF is based on a few practices at the plot level, which combined can provide many systems at the farm level (Nair, 1993; Nair et al., 2022). The most recognized ones are associated with the spatial use of the woody perennials and include the silvopasture, silvoarable/alley cropping, homegardens/kitchengardens, woody linear landscape strips, and forest farming (Table 1), as described by Mosquera-Losada et al. (2018b). Mosquera-Losada et al. (2016) described two main spatial AF practices: silvopasture and alley cropping/silvoarable, which can be enlarged to a third one, named woody linear landscape strips if protection against water contamination (riparian buffer strips) or wind (hedgerows, hedges, and windbreaks) are pursued (Table 1). The fourth practice is homegarden or kitckengarden known as the implementation of silvopasture (e.g., chickens) or silvoarable (vegetables) in urban and peri-urban areas, a practice nowadays promoted by some municipalities across Europe through the Covenant of Mayors launched in 2009 by the European Union and with more than 10,000 municipalities currently involved (European Union (EU), 2022). Finally, the obtention of agricultural products from the understory in forestlands is known as forest farming. From those, silvopasture is the most extended AF practice in Europe, occupying 17.78 million ha in Europe, which together with the silvoarable practices (360 thousand hectares) (Mosquera-Losada et al., 2016, 2018a) reaches almost 20 million hectares of AF practices in Europe. Out of these, there are agroforestry systems implemented in farms using different agroforestry practices (mainly silvoarable and silvopasture) in Europe, such as the 3 million ha of dehesas and montados in Europe (Moreno and Pulido, 2009) and the 40 million ha found in Baltic countries of Europe (Jernsletten and Klokov, 2002). Silvopasture was, together with the silvoarable practices, the most ancient AF practices in Europe, dating from the Neolithic period (Pinhasi et al., 2005), starting in the East, and later on moving on to the west part of Europe (Mosquera-Losada et al., 2012). Woody linear landscape strips are usually naturally developed, but they can also be deliberately planted to prevent water bodies' damage as recommended by the Association for Temperate Agroforestry (AFTA) (2015) in the United States.

There are agroforestry practices implemented at a temporal scale, usually on a year or multiple year bases, which use woody perennials, usually a shrub legume such as *Ulex* spp. was established for a period of 10 years, to restore soil fertility. Improved fallow with woody perennials is an ancient technique (legume *Ulex* used to improve soil fertility) to increase soil health that was used in many places across the globe. In Galicia, shrub legumes such as *Ulex europaeus* or *Ulex gallii* were sown by farmers to increase soil fertility through the inherent addition of organic matter and/or nitrogen. These shrub legumes were sown when the productivity of cereals (mainly wheat and rye) had been significantly reduced. The shrubs were allowed to grow up and annually harvested to provide animal bedding for stables, where the mixture with manure generated an excellent fertilizer and soil amendment. Ten years after sowing the shrubs were harvested, and the roots were extracted and fired in holes following an anaerobic burning in a process named "troleiras," therefore, producing biochar that was afterward applied in the fields. The former shrublands were again sown with cereals, mainly wheat or rye, and became highly productive. Moreover, the period of 10 years with shrubs caused a clear depletion of weed bank seeds in the shrubland sown fields, appearing the cereals clean of weeds without the need for any mechanical treatment.

The most relevant AF practices to promote Smart Climate Change Agriculture in Europe are silvoarable and silvopasture (Mosquera-Losada et al., 2016), which can be implemented in different types of lands such as agriculture or forestry (Table 2). Most often, new AF sites are obtained by planting trees in arable land (silvoarable) to provide several benefits (profitability, environmental benefits, biodiversity, etc.). Similar benefits, however, may be achieved when AF is implemented in existing orchards that might otherwise be abandoned or removed for lack of profit, such as millions of hectares of olive orchards in Europe (Rodríguez-Rigueiro et al., 2021). For example, due to the high harvesting cost and the decoupling of agricultural funding from the production, traditional olive cultivation and other relevant fruit trees are rapidly becoming anti-economical in developed countries (Rodríguez-Rigueiro et al., 2021). Converting such landscape to an olive-based AF system, intercropping olives with other economically viable crops/animals can provide economic sustainability, allowing maintenance of a traditional agricultural landscape, which is also functional for tourism activities. Implementing multipurpose AF fruit trees such as walnut, chestnut, and cherry can be a win–win strategy for increasing valuable timber production in Europe as performed by companies such as Bosques Naturales across Spain. Silvopasture should be promoted as a way to control the understory (therefore, preventing the use of herbicides and reducing the use of fossil fuels when the control is done by mechanical means) not only in high-value tree plantations but also in forest lands by adding

TABLE 1 Spatial agroforestry practices in Europe [modified from the Association for Temperate Agroforestry (Nair, 1994; Association for Temperate Agroforestry (AFTA), 1997; Alavapati and Nair, 2001; Alavalapati et al., 2004; Mosquera et al., 2009; Mosquera-Losada et al., 2018a)].

Scale	Agroforestry practice	Description	
Spatial	Silvopasture		Combining woody with forage and animal production. It comprises forest or woodland grazing and pastoral land with hedgerows, isolated/scattered trees or trees in lines or belts.
	Homegardens or kitchengardens		Combining trees/shrubs with vegetable production in urban areas, also known as part of "trees outside the forest."
	Woody linear landscape strips		Strips of perennial vegetation (trees/shrubs) natural or planted in between croplands/pastures or between croplands/pastures and water sources such as streams, lakes, wetlands, and ponds to protect water quality. They can be combined with arable lands (silvoarable) or grasslands (silvopasture).
	Silvoarable		Widely spaced woody vegetation inter-cropped with annual or perennial crops. Also known as alley cropping. Trees/shrubs can be distributed following an alley cropping, isolated/scattered trees, plot borders.
	Forest farming		Forested areas used for production or harvest of natural standing specialty crops for medicinal, ornamental or culinary uses, including those integrating forest and agricultural lands.
Temporal	Woody perennial fallow		Fast growing, preferably leguminous woody species planted during the fallow phase of shifting cultivation; the woody species improve soil fertility and may yield economic products-

a key component to the agroecosystem: the megaherbivores. The megaherbivores in forest lands play a very relevant role in natural systems: increase biodiversity by reducing understory dominant species, by trampling, and by the selection of the different species and accelerate soil nutrient use by the understory and trees by increasing mineralization rate (urine, mainly composing by ammonia can reduce the C/N relationship), as described by Mosquera-Losada et al. (2012).

TABLE 2 Agroforestry practices linked to dominant land use categories (agriculture, forest, or peri-urban).

Land use and agroforestry practice		Examples	Brief examples and descriptions
Agriculture	Silvopasture	Wood pasture and parkland	Areas used for forage and animal production that includes non-agricultural trees and shrubs.
		Meadow orchards	Areas of agricultural trees and shrubs (e.g., fruit orchards, olive groves, vineyards) which are grazed.
	Woody linear landscape strips	Hedgerows, windbreaks and riparian buffer strips	Woody components are planted to provide shelter, shade, or parcel demarcation to a crop and/or livestock production system. Riparian buffer strips are typically created to protect water quality and can be silvopasture or silvoarable.
	Silvoarable	Alley-cropping systems	Widely spaced woody perennials inter-cropped with annual or perennial crops. As the tree canopy develops, the crops may be replaced with a grass understorey, usually better adapted to shade.
Forest	Silvopasture	Forest grazing	Although the land cover is described as forest, the understory is grazed and delivering agricultural products.
	Forest farming	Forest farming	Forested areas used for production or harvest of naturally standing specialty crops for medicinal, ornamental or culinary uses.
Urban rural and periurban	Homegardens	Homegardens	Combining trees/shrubs with vegetable production usually associated with peri-urban or urban areas but also with areas surrounding houses in rural areas

4. Current agroforestry implementation

The implementation of AF practices is widespread in Europe, whenever woody vegetation is present and managed (Mosquera-Losada et al., 2018b). However, most of the time, there is not a clear relationship between the presence of trees or shrubs and the concept of AF. It means that usually, policymakers are not aware (even farmers or foresters) of the role of woody perennials in agriculture. In addition, the spreading of AF practices is limited by the "most recent intensive modern practices" ideas, i.e., trees are considered a nuisance for mechanical agricultural practices as well as a reservoir of useless insects, nowadays recognized as part of the pollination needs or the biological control of crops' pests and diseases (McAdam et al., 2009). Further important steps should be carried out to spread AF practices in the intensification practices of agricultural systems deeply considering the environment. The lack of recognition by farmers of these AF practices is found elsewhere in developed countries as indicated by the report elaborated by the department of agriculture of the United States [United States Department of Agriculture (USDA), 2013]. The previous report states that AF is currently practiced on <2% of its potential area in the United States, which means that it can be implemented in 369 million ha, probably due to the former implementation of the intensive farming systems, where trees are considered that hinders agriculture production. The degree of implementation at the farm level within the European scale is small and not fully recognized by farmers due to the lack of know-how and knowledge at the field level, which highlights the importance of establishing networks at different levels in order to increase simultaneously productivity and sustainability in agriculture, forestry, and rural areas, put in practice research results insufficiently exploited and taken up in practice, capture, and spread innovative ideas from practices.

In this way, the development of AF in Europe should be based on adequate research and dissemination by taking an adequate multiactor approach as carried out by the different EU projects. The European Union is aware of this and has funded several projects dealing with agroforestry such as AGFORWARD, AFINET, AGROFE, UNDERTREES, AGROMIX, MIXED, and AF4EU that will advance rural development following the recommendations of the World Bank (2012), by the integration of a multiactor approach on their research.

The AFINET project has asked approximately 1,500 AF actors about the main challenges to fostering agroforestry across Europe from an agroecosystem perspective. The actors provided four main fields to act in facilitating the AF implementation across Europe: technical, economic, education, and policy. The **technical challenges** include the knowledge of the best combinations adapted to specific field levels, both the development of multiactor projects to seek more needed research results and the operational groups from the Pillar II of the CAP may be the best available activities to help this purpose. The **economic challenges** are dealing with the economic benefits in the short, medium, and long term that the use of AF may provide compared with the current treeless use but also the possibility of developing adequate labels to recognize agroforestry by the consumer. The **education challenge** has 2-fold needs. The first is the demand for adequate and updated extension services across Europe, which has been promoted in the post-2020 CAP, and the second one is related to the consumers, including schools. Actors claim that consumers should be aware that taking care of the environment is associated with the type of products the surrounding land produces. The **fourth challenge** is linked to adequate business environment development through policies, specifically claiming for two aspects: the support for the transformation to AF and the maintenance of current AF systems from an agroecosystem perspective but also the promotion of adequate value chains, mostly short to foster healthy and more environmentally friendly food.

5. Agroforestry and policy in Europe

The importance of AF to foster economically viable and sustainable development in agriculture, forestry, and rural areas has been recently recognized by countries such as the United States [United States Department of Agriculture (USDA), 2011] and India (Indian Ministry of Agriculture, 2014), which already published national AF strategies to enhance and promote the use of AF systems on their forestry and agricultural lands CAP is composed of two Pillars: Pillar I, which is completely financed by the European Commission, and Pilar II, whose measures have to be cofinanced by the Member States. In addition to that, AF practices have been included in different EU strategies (climate change, forestry strategy, biodiversity strategy, etc.) to promote land use sustainability. The potential of AF to contribute to the CAP goals is shown in Table 3.

Europe has indirectly recognized the role of the woody vegetation outside the forest between 2007 and 2013 as part of the conditionality and the enhanced conditionality conditions (Santiago-Freijanes et al., 2018a). The conditionality is a mechanism that links direct payments (Pillar I) to comply by farmers with basic standards concerning the environment, food safety, animal and plant health, and animal welfare, as well as the requirement of maintaining land in good agricultural and environmental condition. The conditionality considers the preservation of landscape features, which includes features such as isolated trees or hedges that can be considered AF (Santiago-Freijanes et al., 2018a). However, there is not an official inventory of these landscape features carried out within the CAP, which makes it difficult to evaluate efficiently the role of CAP in their preservation as highlighted by the European Court of Auditors (2009).

Europe has politically recognized the important role that AF systems have to play from a productive and environmental point of view through the inclusion of a measure to promote AF establishment in the Rural Development Program (Pillar II) within the CAP framework in the period of 2007–2013 and 2014–2020 with the measures 222 and 8.2 (Santiago-Freijanes et al., 2018a,b). However, as happened for the successive agroforestry strategies in the United States [United States Department of Agriculture (USDA), 2013], the degree of implementation of AF in Europe due to these measures was and is limited, and in the case of Europe, mostly limited to Hungary in the period of 2007–2013. The relatively low success of Measure 222 and 8.2 of RD Programs (CAP 2007–2013) can not only be due to the lack of knowledge that farmers have about how to establish AF in their environments but also due to the competing forestry measures (221 and 222 and 8.1 for the 2007–2013 and 2014–2020, periods) that allows to plant trees and pays for a long period of time (between 15 and 25 years) without any further activity in the land included agroforestry, as discussed by Santiago-Freijanes et al. (2018a). Moreover, the Rural Development Program (Pillar II) also establishes a measure to prevent forest fires to be implemented in those countries with higher forest risk consisting of forest grazing that is not considered AF as such.

The CAP of the period of 2014–2020 has favored AF preservation by the definition given to the "permanent pasture" concept, the maintenance of isolated trees and hedges as landscape features to be preserved (GAEC), and by the recognition of AF as an activity in the Ecological Focus Areas within the greening payment of Pillar I framework. The definition of permanent pasture is as follows: "*Permanent pasture means land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in the crop rotation of the holding for five years or more; it may include other species such as shrubs and/or trees which can be grazed provided that the grasses and other herbaceous forage remain predominant as well as, where Member States so decide, land which can be grazed and which forms part of established local practices where grasses and other herbaceous forage are traditionally not predominant in grazing area*" (Regulation 1307/2013). Therefore, it accepts for the first time in the Pillar I CAP to have a woody or even a predominant woody component in the plot to be funded by direct payments. Moreover, the greening included agroforestry as part of the activities to be funded but only if the establishment was previously funded by the Pillar II 222 and 8.2 measures, which were not very successful as aforementioned. Pillar II of CAP 2014–2020 also kept the measures directly related to AF: agroforestry establishment and forest grazing in high-fire-risk forests linked to silvopasture practice. The degree of implementation of AF in Europe will depend on the knowledge of these types of practices at the European level.

The post-2020 CAP is fostered to adopt agroforestry through the use of the eco-schemes and a higher responsibility of the member states to adopt sustainable practices, such as agroforestry, better adapted to their conditions. This is especially relevant with the concept of the eligibility of the agricultural lands to perceive CAP funds usually linked to the "eligibility" concept strongly dependent on the number of trees per hectare, without considering if agricultural products are produced or not with these trees. The link of direct CAP payments to lands with tree density has unfortunately caused millions of trees destruction across Europe. The European Commission established a limit of 50 and 100 trees per hectare as a limit to perceive direct payments of the CAP for the 2007–2013 and 2014–2020 periods, respectively, but fortunately, no tree limit is imposed on the member states to make the land eligible for the direct payments in the 2021–2027 CAP period by the European Commission. This allows member states more flexibility to include woody perennials in their lands to foster sustainability, increase biodiversity, and combat climate change. The number of research activities to demonstrate the sustainable intensification that AF provides has increased in an exponential way during the last two decades (Mosquera-Losada et al., 2005; Rigueiro-Rodríguez et al., 2009; Mosquera-Losada and Prabhu, 2019; Nair et al., 2022). These research activities have demonstrated the important role that woody vegetation plays to increase farmer incomes while providing ecosystem services in both forestry and agricultural lands in Europe and all over the world.

TABLE 3 Agroforestry support for the post-2020 CAP goals.

CAP Post-2020 goals	AF fulfillment
Contribute to climate change mitigation and adaptation as well as sustainable energy	AF is one of the most powerful tool to mitigate and adapt farming systems to climate change [Food and Agriculture Organisation (FAO), 2015] while providing biomass based renewable energy sources.
Foster to sustainable development and efficient management of natural resources such as water, soil and air	AF increases biomass production per hectare thanks to the increase of the sun radiation use and nutrient recycling by tree root uptake the excess of leached nutrients, therefore improving air, soil and water quality.
Contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes	AF is able to protect and increase biodiversity thanks to the habitat heterogeneity it creates, but also enhance Ecosystem services delivery (e.g., use of local breeds and the capacity they have to link habitats and landscapes).
Support viable farm income and resilience across the Union to enhance food security	The optimization of the resources use and the multiple products delivered under AF schemes will increase farm income and food security.
Enhance market orientation and increase competitiveness, including greater focus on research, technology and digitalisation	Digitalisation, innovation farmer led research and technology development to implement AF foster farm competitiveness through the multiple products delivered from the same land associated to new market opportunities at local and global level.
Improve the farmers position in the value chain	The increase of the number and quality of products delivered by a farm allows farmers to have a better position in the value chain and be more resilient to climate and market changes.
Attract young farmers and facilitate business development in rural areas	AF systems are complex and need educated and skilled young people that can have on them a business opportunity in the rural areas development, including short, medium and long term profits linked to retirement.

The main drawbacks to spreading AF practices are related to knowledge gaps such as the selection of appropriate crops/trees or shrubs and/or animals adapted for specific environments, the best forms of management (including woody vegetation distribution and tree aging) to increase production per unit of land and improve adaptation and mitigation to reduce the impact of climate change at the plot, farm, and landscape scales (Mosquera-Losada et al., 2017). The AF communities need knowledge integration with experts in both agriculture and forestry to use the latest techniques in order to enhance the productivity of already treeless agriculture's existing systems through better adaptation (i.e., increased resilience) to climate change while reducing GHG emissions. From this point of view, AF is a cross-border field of research that has not been sufficiently addressed in Europe. Further research can take advantage of already known techniques that are used in a range of European environments (Southern and Northern countries) and a range of marginal to productive lands.

Some of the advantages of AF practices stem from the high biodiversity they foster; therefore, their promotion and preservation are essential, as for example, traditional genetic resources of traditional crops or livestock breeds vulnerable to extinction needed to obtain better varieties and breeds adapted to woody vegetation (shade, consumption), as described by Rigueiro-Rodríguez et al. (2012). In addition, traditional forest trees, AF also includes high-value fruit and timber trees (including local varieties) which have marketable products while enhancing amenity values, biodiversity, and soil protection, in particular on slopes of hills and mountains. The range of food products produced by such trees can also contribute to the healthy diets and lives of consumers of EU citizens (Mosquera-Losada et al., 2016).

The results of a study conducted to understand how the CAP has fostered silvopasture in the Mediterranean areas or Europe conclude that silvopasture is an important practice across the Mediterranean region (Rodríguez-Rigueiro et al., 2021), mostly associated with Oaklands but also present in permanent crops (olive) in some areas. In contrast, silvoarable practices are currently very poorly implemented across the EU (Mosquera-Losada et al., 2022). The extent of silvopasture is high in the west part of the Iberian Peninsula where the share of public land is low as financial benefits are obtained from the land (Rodríguez-Rigueiro et al., 2021). However, most of the regions have a low extent of silvopasture which can be linked to high (intensive agriculture) and low (abandonment) anthropogenic pressure (Mosquera-Losada et al., 2022). Most of the policy measures related to silvopasture are adapted to the local necessity. The already existing agroforestry-managed land (dehesas/montado) is related to measures supporting regeneration and maintenance, while in those areas, where agroforestry does not exist, the measures are related to forest fire prevention. In contrast, silvoarable practices can be implemented in much of the Mediterranean agricultural lands, increasing the delivery of ecosystem services. Therefore, both silvopasture and silvoarable practices should be promoted by the CAP considering the enhancement of the extension services activities but also the development of adequate supply and value chains.

6. Agroforestry for the future CAPs

The AFINET EU project highlighted a set of 15 recommendations to foster AF implementation that have been considered for CAP 2021–2027. Considering the premise that agroforestry should be strongly supported by the CAP, because it is a sustainable land management option that delivers market and non-market goods and services and addresses the UN Global societal goals, the governments need to develop policies and actions that foster agroforestry within an EU policy framework.

The first recommendation is associated with the adoption of a global definition of agroforestry that fulfills all types of AF currently used in Europe "the deliberate integration of woody vegetation (trees and/or shrubs) as an upper story on land with pasture (consumed by animals) or an agricultural crop in the lower story," being the woody vegetation evenly or unevenly distributed in the borders or inside of the plots (Mosquera-Losada et al., 2018a).

The second recommendation is related to the fact that AF is based on two practices applied at the plot level: silvopasture and silvoarable that are converted in five practices considering the land and the role they play such as the riparian buffer strips, the linear woody landscape strips (hedges and hedgerows), forest farming, and kitchengardens/homegardens. AF linked to agricultural lands are those related to silvopasture (e.g., wood pasture and parklands or meadow orchards), hedgerows, windbreaks, riparian buffer strips, and silvoarable, also known as alley-cropping systems.

The third recommendation deals with the fact that woody vegetation promotion and preservation linked to landscape features policies associated with Pillar I and Pillar II payments should be simplified and objectives should be clearly stated, and administrative burden reduced.

The fourth recommendation aims at recognizing the full eligibility of arable and permanent grasslands of AF lands adapted to member states' conditions. AF should be acknowledged as such with a management plan, including a minimum/maximum tree density or canopy cover to be selected by member states, an initial and final tree density or canopy cover, and the pursuit of a final maximum tree density or canopy cover. There is an important opportunity to reach this goal within the post-2020 CAP Strategic Plans of the EU member states. Moreover, an AF option should be implemented in all three categories of land use paid by the CAP direct payments (arable land, permanent grassland, and permanent crops to be promoted), to recognize the sustainability of the AF systems for farmers and policymakers as well as the carbon sequestration potential they have to reach climate neutrality.

The fifth recommendation deals with the arable land fully eligible for direct payments with a minimum and maximum tree density or canopy cover, if needed, selected by member states different from young and mature woody vegetation and the inherent recognition of the ecosystem services this woody vegetation delivers for the arable lands, to make understandable the services they provide for all actors involved in agriculture.

The sixth recommendation is associated with the fact that AF should also be fully eligible for direct payments in permanent grasslands through the (i) establishment of a minimum and maximum tree density or canopy cover, if needed, that should be selected by member states, (ii) use of woody perennials as feed to reduce farm production costs, and the (iii) recognition of ecosystem services.

The seventh recommendation is associated with permanent crops that are already fully eligible for direct payments where the implementation of silvopasture or silvoarable practices should be fostered through the double or an increasing payment based on both the understory (cereals, meat) and overstory (fruit) products.

The eighth recommendation highlights that AF should have been part of the greening in a better-designed way and should be part of the eco-schemes of the post-2020 CAP.

With regard to Pillar II, the ninth recommendation aims to develop a unique AF measure encompassing the five agroforestry practices: silvopasture, silvoarable, woody linear landscape strips, forest farming, and homegardens, as shown in Table 2 to be funded by Pillar II, being those AF Pillar II funded practices implemented in any of the arable, permanent grassland and permanent crops fully eligible for the Pillar I direct payments.

The tenth recommendation is linked to the support of AF establishment or management on agricultural lands, mostly including maintenance payments similar to those related to afforested or reforested lands with an adequate management plan and clear definitions of tree densities associated with young and old trees. All AF practices paid by Pillar II should be recognized as eligible for direct payments in Pillar I.

The eleventh recommendation is associated with the support of AF establishment or management in forest lands recognizing both forest farming and forest grazing and including the forest grazing measure as part of the AF practice.

The twelfth recommendation deal with the recognition of AF at the farm level and should be associated with the climate neutrality concept as a way to contribute to the European targets related to climate change, improving resource use, farming system resilience, biodiversity, and water quality, among others. This recommendation will help to recognize the role of AF in sustainability.

The thirteenth recommendation is associated with the cooperation measures for sustainable landscapes, which are currently fostered through the use of the operational groups that became international in the post-2020 CAP.

The fourteenth recommendation is associated with the promotion of the AF value chain, highlighting the potential that consumers recognize the land sustainability coming from products delivered from AF practices and the promotion of the circular economy.

The last recommendation is associated with the need for education for AF, through the development of activities linked to the EIP-Agri framework, extension services, and knowledge co-creation that should be promoted.

Finally, all these recommendations need to have a global framework associated with the development of a European agroforestry strategy, as has been carried out in the United States, India, or Mexico, among other areas of the globe.

7. Conclusion

There is a strong need to gather AF information from different research disciplines and practices to compare the results with local treeless systems within different pedoclimatic conditions and countries. The results should be available for researchers, stakeholders, farmers, foresters, and policymakers in order to promote the use of AF practices and acknowledge the ecosystem services AF provides. This will be the basis to define a clear policy strategy for AF. Promoting agroforestry practices, which combine valuable timber/fruit trees with agricultural activities, is a key strategy for increasing owner income from multipurpose use of land while enhancing the environment and ecosystem service delivery. Technical, economic, educational, and policy challenges should be overcome with the development of multiactor activities fostered by thematic networks, multiactor projects, operational groups, and an adequate AF advisory system development in Europe linked to the agroecosystem and their respective value chains and associated with research and practical implementation. A European agroforestry strategy is needed to provide a framework to be recognized by member states, with the possibility of acknowledging the ecosystem services delivery from AF.

Author contributions

JJS-F: supervision. MRM-L: writing—original draft. MRM-L, MS, BG, NF-D, MC, AR-R, MPG-H, JLF-L, RR-F, JA-V, CS, JJG-B, and JJS-F: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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