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Global and European policies to foster agricultural sustainability: agroforestry

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Abstract Agroforestry is a sustainable land management system recognized worldwide but not implemented in a extensive form in temperate and developed countries. Agroforestry has been promoted in the last decades at global level as it provides more efficient and sustainable farming systems. This review aims at summarizing the main research findings explaining why agroforestry is a sustainable land management that fulfils and is affected by different Global, Pan-European and European policies as well as how innovation is currently fostered in Europe, therefore linking research, policy and innovation. This review specially targets researchers and policy makers working in integrated land systems. There is a global and European recognition of the role that agroforestry can play to provide products but also to deliver highly important ecosystem services. However, the promotion of agroforestry practices at European level is still not well addressed by the Common Agricultural Policy. The clear identification of agroforestry practices, the link of management plans to establish agroforestry pursuing a final eligible tree density for the Pillar I payments should be addressed as initial steps to foster agroforestry in Europe. There is a lack of knowledge transfer that promotes agroforestry at field level, which should be approached by using stakeholder integration within the policy development as it is currently done by the EIP-Agri.

Keywords CAP · Innovation · United Nations · Biodiversity · Ecointensification

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Introduction

Intensive farming systems have been promoted in the last century all over the world causing many environmental problems as well as agricultural ecosystem degradation linked to the loss of some ecological traits, such as the presence of the woody component (Rigueiro-Rodríguez et al. 2009; FAO 2010; Buttould 2013). Intensive farming systems are mainly based on external inputs usually brought far away from the farm (i.e. phosphorous) or artificially created (i.e. nitrogen). These external inputs cause a high carbon foot print, if energy consumption related with the transport from abroad the fields or the industrial synthesis are considered. Agricultural and forestry systems are currently expected to deliver as much ecosystem services as possible including those linked to the provision, regulating and cultural ecosystem services as declared by the Common International Classification of Ecosystem Services named CICES (Haines-Young 2016). The delivery of ecosystem services is related with the provision of food for a growing world population considering sustainability to allow future human generations to fulfil their needs (FAO 1989, 2014). Moreover, the role of ecological processes in agricultural sustainability has been studied for many years (Swift and Anderson 1994), and its importance for the future of global agriculture is well recognized (Tscharntke et al. 2012). Therefore, farming systems should switch from intensive to extensive that is to say from external inputs use to the efficient use of the available resources which can be based on biodiversity (Gross 2016; Rois et al. 2006; Rigueiro-Rodríguez et al. 2011; Leakey 2014).

Agroforestry, the deliberate integration of a woody component with an agricultural production in the lower storey is declared as a sustainable land management practice. It increases ecosystem services delivery from farming systems through the recovery of degraded land and the optimization of the use of the resources of those farming systems that are in better conditions (Rigueiro-Rodríguez et al. 2009; FAO 2014). Moreover, agroforestry is seen as one of the most important tools to help agricultural and forest land to mitigate and adapt to climate change (Buttould 2013) compared with unmanaged forest and treeless systems, an important current and broad problem affecting worldwide.

Agroforestry policy promotion is not easy because of various reasons (Buttould 2013; Rois et al. 2006) such as the lack of knowledge about the best combinations of the woody and the agricultural components adapted to specific site conditions, but also due to the inertia of intensification of most agricultural practices carried out by farmers. On this regard, different NGOs and international organizations on which farmers and researchers are working together initiate movements all over the world trying to highlight the important role that agroforestry has to play as a form of multipurpose system based on ecointensification (i.e. optimization of the use of the resources to deliver more products). These NGOs are the ICRAF or World Agroforestry Centre (http://www.worldagroforestry.org/) operating mainly in tropical countries, the AFTA (Association for Temperate Agroforestry (http://www.aftaweb.org/)) associated to North America Countries (Mexico, USA and Canada) or EURAF (European Agroforestry Federation www.eurafagroforestry.eu) involving more than 20 European countries. Agroforestry is also seen as an excellent tool to be used in less intensive farming systems based on mixed farming (EIP-AGRI 2016), organic farming and agroecology (Leakey 2014) permaculture (Ferguson and Lovell 2013) or as far as they use a woody component to increase fertility or to extend the grazing season for livestock feeding to reduce the need of external inputs, among others. These movements could be associated to the recent Agroforestry National strategies which try to promote agroforestry in different countries. This has happened in several continents of the world including those described in the United States (US Department of Agriculture 2013; US Government 2015), India (Indian Government 2014), Mexico (CONAFOR 2017) and France (French Ministry of Agriculture 2016). The European Commission has also included agroforestry as a practice in the Common Agrarian Policy (CAP), the main supporting tool for farmers in the 28 European Union countries. These strategies are based on global policies that, in the case of Europe are subsequently integrated in Pan-European and different European strategies based on which CAP is constructed. Some of the policies are focused on agriculture and others on the environment, forestry or sustainable development. This review aims at summarizing the main research findings explaining why agroforestry is a sustainable land management and how different Global, Pan-European and European policies are currently fostering agroforestry in Europe,

therefore linking research, policy and innovation. This review specially targets researchers and policy makers working in integrated land systems.

Materials and methods

This review has been carried out after consulting relevant documents at global scale including United Nations, FAO and European policy bodies. We also searched the web pages, reports and other papers to evaluate the impact of policies on agroforestry. The reviewed policies are those included in Table 1.

Results and discussion

Global policies

Global policies related to agroforestry are considered in terms of the FAO Guidelines for Sustainable Agriculture and Rural Development, the Orlando and Lugo declarations, the Global Research Alliance, and the Millennium Development Goals. These are considered in turn below.

The FAO (1989) has defined *Sustainable Agriculture and Rural Development* as "the management and conservation of the natural resource base, and the orientation of technological and institutional changes…to ensure the attainment of continued satisfaction of human needs for present and future generations". The same report indicates that sustainable agriculture and rural development requires the conservation of resources such as air, soil and water quality, and a diverse genetic base, whilst ensuring that activities are "environmentally non-degrading, technologically appropriate, economically viable and socially acceptable" (FAO 1989).

In 2014, FAO suggested five principles to guide strategic global development to provide "a basis for developing national policies, strategies, programmes, regulations and incentives that will guide the transition to an agriculture that is highly productive, economically viable, environmentally sound, and which is based on the principles of equity and social justice". These principles can be considered in relation to agroforestry.

Principle 1: *Improving efficiency in the use of resources is crucial to sustainable agriculture* Agroforestry practices commonly enhance resource use in terms of the capture of solar radiation, water and nutrients at plot level. Hence outputs per unit of land under agroforestry are typically higher than that under a monoculture arable crop or a monoculture tree crop

Table 1 Global, Pan-European and EU organizations and agreements delivering policies relevant for agroforestry

Scale	Policy
Global	FAO Sustainable Agricultural and Rural Development
	Millennium Development Goals
	Orlando and Lugo Declarations
	Global Research Alliance
	Global Alliance for Climate Smart Agriculture
Pan-European	Ministerial Conference 'Environment for Europe'
	Ministerial Conference 'Forest Europe' (former MCPFE)
	Pan-European Biodiversity and Landscape Strategy (PEBLDS)
	European Convention on Landscapes
EU	Seventh Environment Action Programme to 2020
	European Biodiversity Strategy to 2020
	Natura2000 - Habitats and Birds Directives
	European Strategy for Sustainable Development´ Bioeconomy
	European Climate Change Programme (ECCP)
	European Forest Strategy
	Cork 1.0 and 2.0 strategy
	Common Agricultural Policy CAP

(Fig. 1). This is specifically quantified by the concept of the land equivalent ratio (LER): the ratio of the land area of monoculture crop and woodland systems required to achieve the same outputs as the agroforestry system. In deriving the LER, it is important to select the appropriate monoculture systems for comparison. Modelled values for the LER for silvoarable agroforestry systems range from 1.0 to 1.8 (Graves et al. 2007; Dupraz and Liagre 2008). This means that one hectare of agroforestry delivers the same products than 1.0–1.8 ha of monocrop (forestry and agricultural products).

Principle 2: *Sustainability requires direct action to conserve, protect and enhance natural resources* Agroforestry can help to reduce some of the negative externalities associated with intensive agriculture such as soil organic matter loss and nutrient leaching. Agroforestry also increases some positive externalities, for example planting trees on agricultural land will increase aboveground carbon storage and enhances biodiversity at a range of scales (Rigueiro-Rodríguez et al. 2009). The combination of woody vegetation with grass and/or crops can create a wider variety of niches which can support a greater diversity of plants adapted to the different microclimatic environments (Fig. 2), and thereby increases microbial and fauna biodiversity. The combination of woody vegetation with animals (at appropriate stocking rates) also tends to increase biodiversity as (1) animals select some plant species instead of others, and (2) they unevenly fertilize the soil, creating patches of varying fertility which favour different plant species, and (3) animal trampling generates micro perturbations allowing annual species to share the same plot than perennials (Buttler et al. 2009; Rosa-García et al. 2012; EIP-AGRI 2016). If more than one animal species is allowed to graze, their different behaviour also improves biodiversity because they select different species (i.e. goats feed preferably on woody vegetation) but also because the form of their mouth and grazing action allows some plant species to grow better than others (i.e. *Agrostis* spp. adapted to sheep grazing) as shown Rigueiro-Rodríguez et al. (2009).

Principle 3: *Sustainable agriculture will protect and improve rural livelihoods and social well-being* Agroforestry can increase production and thereby the revenue from a given area of land. Higher revenue is linked to higher need of man-power and therefore jobs. Some agroforestry practices can provide a basis for eco-tourism (Pardini 2009), for example many traditional systems have a high cultural value. The diversity of outputs also means that agroforestry can be a more resilient system that helps farmers to counteract shortage periods or unusual catastrophic events (i.e. flooding, heatwaves, and droughts).

Principle 4: *Sustainable agriculture must enhance the resilience of people, communities and ecosystems, especially to climate change and market volatility* The multipurpose use of land is likely to be more resilient than monoculture systems as a crop failure can be compensated by the sale of the other crop. For

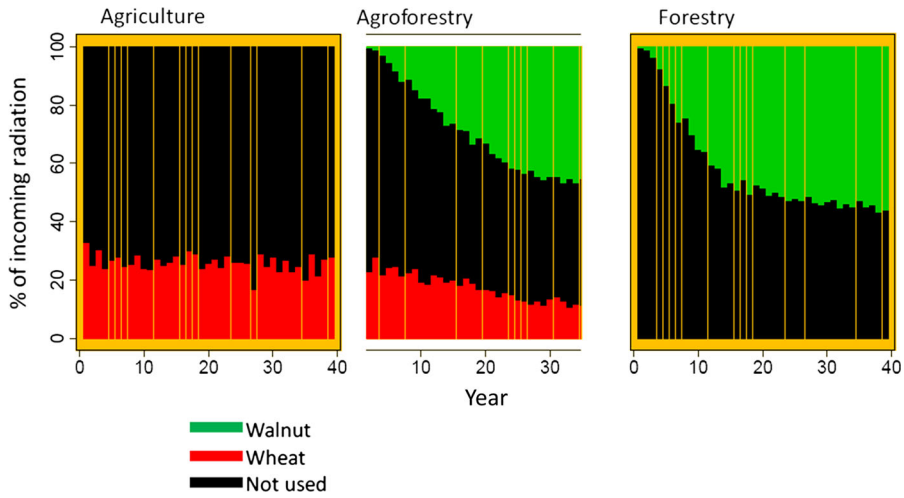

Fig. 1 Modelled proportion of solar radiation intercepted by a wheat monoculture, a wheat-walnut agroforestry system, and a walnut forestry system over 40 years (Dupraz and Liagre 2008). (Color figure online)

Fig. 2 Tree shade effect on below tree vegetation at the end of the growing season in the dehesa, promoting the extension of the growing season to feed animals (Gerardo Moreno, University of Extremadura, Spain). (Color figure online)

example, where oak trees are pruned every 2 years out of 10 years in the Mediterranean, they can provide "extra feed" during "bad years". In addition, agroforestry practices such as the grazing of forest understories can reduce forest fire risk. The effects of agroforestry on the vulnerability to climate change has been reviewed by Schoeneberger (2008) and Thorlakson and Neufeldt (2012). Adaptation is also an excellent tool to increase resilience of grazing systems as they are able to extend the grazing season in some environments (Fig. 2).

Principle 5: *Good governance is essential for the sustainability of both the natural and human systems* Agroforestry is a deliberate land use practice that requires good governance, supported where possible by adequate agroforestry policies, such as in India (Indian Government 2014), the USA (US Department of Agriculture, Office of the Secretary 2011) and France (French Ministry of Agriculture 2016) as recommended by the FAO (2015).

Another key concept delivered by FAO is the promotion of "Good Agricultural Practices" which aim to ensure safety and quality of products in the food chain (Tscharntke et al. 2012), capture new market advantages by modifying supply chain governance, improving natural resource use, workers health, and working conditions, and/or creating new market opportunities for farmers and exporters (FAO 2015), which all contribute to sustainable agriculture and rural development (SARD). Sustainability concepts are promoted through different policies and strategies like those shown in this review.

The United Nations (UN) has agencies such as FAO focused on agriculture, and programs such as United Nations Development Programme (UNDP) and United Nations Environment Program (UNEP) focused on the environment. The UN has also a specific regional commission in Europe called the UN Economic Commission for Europe (UNECE).

In 1992, the Commission for Sustainable Development of the United Nations organized, the Conference of the United Nations on Environment and Development (UNCED) in Rio de Janeiro, known as the Rio Summit. Several multilateral environmental agreements were signed: Convention on Biological Diversity (CBD), Convention on Climate Change (UNFCCC), Convention to Combat Desertification (UNCCD) and the Rio Declaration on Environment and Development. Agroforestry's role in sustainable development was recognised in the UN Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD), and within the Forest Principles (not binding) and the

action plan 'Agenda 21', which were also developed in the Rio Summit.

Agenda 21 tackles current environmental problems and looks towards the achievement of a world-wide sustainable development. It describes the need to (1) combat deforestation and prevent erosion, (2) combat desertification and drought, (3) support sustainable development in mountainous areas, (4) promote agriculture and sustainable rural development through multidisciplinary research and technology transfer, and (5) to conserve biodiversity. In each of these areas, agroforestry can play a role. Agroforestry can be used to increase vegetation cover to combat desertification, reduce erosion problems and help with land restoration. Agenda 21 also states that measures should be taken to "improve the rate of returns on investments in planted forests, through interplanting and underplanting valuable crops". Again this highlights the important role that agroforestry has to play. Agenda 21 supports sustainable forestry, the expansion of areas under forest and tree cover, and highlights agroforestry as a sustainable land management practice. Agroforestry, as already described, can help to protect forests by reducing fire risk. It can also provide additional revenue to the private sector and rural communities by allowing the creation of new products or high value services such as ecotourism.

In the Fourth Forum on Forests (United Nations 2004), it was suggested to connect the "Millennium Development Goals" (United Nations 2000) with the National Forest Programmes, due to the relationship between sustainable forest management and poverty reduction and at the same time maximize the potential benefits of agroforestry according to a better spatial planning. This can be achieved at different scales: at plot level (woody + annual perennial crops), farm level (strategic use of resources within a year framework) and landscape level (promoting ecosystem services delivery). Such Millennium Goals are a key aspect in the agenda of global development (Garrity 2004), and research and development of agroforestry can contribute to the achievement of many of the objectives including increasing income and improving human wealth, promoting gender equality and environmental sustainability. In fact traditional agroforestry systems are being recognized in tropical areas, and their multifunctional role is also increasingly appreciated in North America and Europe where governments have significant roles in promoting such systems in relation to market access, debt relief programmes, and investments.

The 'Orlando Declaration on Agroforestry Systems' was made at the First World Agroforestry Congress in the USA in 2004 (First World Congress of Agroforestry (Orlando Declaration 2004). The Declaration declared that agroforestry could address issues of climate change and biodiversity conservation, and increase incomes, promote gender equity, improve health and wellbeing, and promote environmental sustainability. It called for an increase of funding and for agroforestry to be a key component of natural resources management.

The 'Lugo Declaration on Silvopastoral Systems' was made at the 'Silvopastoralism and Sustainable Management International Congress' in Spain in 2004. It highlighted the economic, ecological and social benefits of silvopastoral agroforestry and its role in rural development, and called for its promotion and research covering topics such as traditional knowledge, management, technology transfer, and capacity-building (Mosquera-Losada et al. 2006, 2007). Such declarations were agreed by qualified scientists from all over the world highlighting the importance of agroforestry in terms of sustainable land management and the need to include them in the political agenda.

The Global Research Alliance (GRA) was created in 2009 at the UN Climate Change Conference in Copenhagen. It seeks to support policies, research collaboration, the exchange of information and technology, and capacity building related to climate change. At the Tampa meeting in 2014, the GRA highlighted the global role of agroforestry to reduce and counteract greenhouse gas emissions. In December 2015, the France launched in collaboration with GRA the 4 $^{0}/_{00}$ initiative (Four per thousand initiative 2015) to counteract the current carbon emissions by storing an additional 0.4% carbon in soils each year. Agroforestry can help to support carbon storage by increasing the above-ground storage of biomass, and in some cases it can increase both the level and resilience of soil C in deeper soil layers than monocrops or herbaceous vegetation (Mosquera-Losada et al. 2011). This was also highlighted in the conclusions of the Global Research Alliance meeting held in Rome in July 2016. A specific group on agroforestry (GRA 2017) has been created within the Global Research Alliance.

The climate-smart agriculture (CSA) concept was promoted at the Hague Conference on Agriculture, food security and climate change in 2010, through the paper "Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation", with a specific chapter on agroforestry (FAO 2010). CSA is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change. CSA specifically mentions that achieving the transformations required for CSA needs an integrated approach that is responsive to specific local conditions. Coordination across agricultural sectors (e.g. crops, livestock, forestry and fisheries) as well as other sectors, such as with energy and water sector development is essential to capitalize on potential synergies, reduce trade-offs and optimize the use of natural resources and ecosystem services. Hence agroforestry is key to this new form of understanding agriculture.

FAO (2013) has also highlighted the importance of agroforestry in "Smart Climate Agriculture" (Buttould 2013). Agroforestry was considered to be a more effective mitigation and adaptation technique to improve food security, than practices such as pasture and grazing management, animal breeding, animal husbandry and health and weather indexed insurance. However the main constraints to the adoption of agroforestry were related to technical and economic issues. In the FAO (2013) book, it is mentioned that "private actors (i.e. multinational businesses) seeking to offset their carbon footprints by purchasing emission reductions on the carbon markets represent a viable source of financing for agricultural climate change mitigation projects, including those that promote agroforestry". The area of agroforestry is seen as an indicator of the Climate Smart Agriculture adoption in farms. For Buttould (2013), agroforestry promotion should be enacted as a method to: protect and sustain agricultural productive capacity, ensure food diversity and seasonal nutritional security, diversify rural incomes, strengthen resilience to climatic fluctuations and perpetuate local knowledge and social and cultural values.

In 2014, the *Global Alliance for Climate Smart Agriculture* was developed to make it easier to establish the tools needed for climate smart agriculture practices. The current implementation of agricultural activities linked to climate change is based on the *Kyoto protocol* which was adopted at the end of 1997 in Japan, committing industrialized countries to stabilize greenhouse gas emissions based on the principles of the Conventions. It entered into force in 2005, with the intention to reduce an average of the 5% emissions compared with 1990 levels over the 5-year old period 2008–2012. Later on the Doha Amendment to the Kyoto Protocol was adopted to be implemented from 1 January 2013 until 2020. Parties committed to reduce greenhouse gas (GHG) emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020, but countries involved are different in the first and second period. The Kyoto Protocol limits the accounting of emissions and removals from land use, land use change and forestry (LULUCF) by Annex I of the Parties. These limitations are associated to those activities defined under Article 3, paragraphs 3 and 4. Paragraph 3 is related with human-induced land conversion including afforestation and reforestation considered as a whole (AR) and deforestation (D). Moreover, Paragraph 4 is dealing with those lands that have not undergone conversion since 1990 and are subject to a specific land use. These activities are related to forest management (FM), crop management (CM), Grazing land management and Revegetation. Within a commitment period once a land area is classified as AR or D, it cannot be included in paragraph 4. Thus, while it is possible, for example, that AR land is later subject to FM, or that D land is later subject to CM, the land must remain classified under Article 3, paragraph 3, for the entire commitment period. However, a land area can change classification from AR to D if land that was afforested or reforested after 1989 is later deforested prior to the end of the commitment period. The classification of a land area as D is permanent for the commitment period, whenever it happens, highlighting the importance of reducing reforestation. Within the LULUCF activities, the preservation of soil C in the terrestrial ecosystems and the promotion of soil C increase are highly relevant, because 81% of C of terrestrial ecosystems is stored in soils (Karsenty et al. 2003). In addition woody vegetation also stores carbon within its biomass on a perennial basis. Moreover, agroforestry will play an important role for the fulfilment of the Paris agreement (2015) aiming at to strengthen the global response to the threat of climate change in the context of sustainable development.

Pan-European policies

The UN Economic Commission for Europe (UNECE) supports the "Ministerial Conference Environment for Europe" which provides a high-level platform for stakeholders to discuss, decide and join efforts in addressing environmental priorities across the 56 countries of the UNECE region. It is a regional UN pillar of sustainable development.

In 2003, at the Fifth Conference of Environment for Europe, ministers agreed within the *Kiev Resolution on Biodiversity* to identify the "high nature value" (HNV) farms by 2006 and to adopt necessary conservation measures (UNECE 2003). HNV farms include agroforestry systems such as dehesas and montados. Economic pressures have caused and continue to threaten the abandonment or intensification of large areas of HNV farmland, with irreversible losses of the associated habitats and species of European importance for biodiversity. HNV farming in European farms is essential for Europe to meet the EU 2020 biodiversity targets. Many of the HNV areas are included as areas to be paid by different European Rural Development Programmes such as measures supporting less-favoured areas, agri-environment interventions programmes, and organic farming.

The Seventh Conference of Environment for Europe in 2011 focused on sustainable management of water and greening the economy. It highlighted the need to ensure that further economic growth was not associated with environmental degradation, and this could be supported by quantifying externalities, stimulating green investment, supporting policy instruments to promote resource efficiency, and supporting relevant research, innovations, education and training. Agroforestry was identified as a sustainable land use and an eco-intensification tool for the EU, with a particular focus on the use of agroforestry to improve water quality through riparian practices.

The Ministerial Conference on the Protection of Forests in Europe (Forest Europe, former MCPFE) is a political platform for promoting European cooperation on the opportunities and threats to the forest sector. It recognises the importance of multifunctional silviculture including both wood and non-wood forest products. The Seventh Ministerial Conference on the Protection of Ministerial Conference on the Protection of Forests in Europe (2015a, b) was held in Madrid. It highlighted that forests and other wooded land provide a multitude of renewable functions and services such as wood production, the protection of soil and water resources and protection from various hazards, climate regulation, carbon sequestration, recreation, use of non-wood forest products, and maintaining biodiversity. However, there is not a real inventory of non-wood forest products to promote their use.

The Pan-European 2020 Strategy for Biodiversity (PESB) was endorsed as the successor of the Pan-European Biological and Landscape Diversity Strategy and Landscape Strategy (PEBLDS 2015), which was set up after adoption of the UN Convention of Biological Diversity in 1992. It aims to provide an innovative and proactive approach to stop and reverse the degradation of biological and landscape diversity in Europe. It has a 20-year vision and framework for Europe to promote a consistent approach to implement the convention on biological diversity. In the action plan, the themes include: the consideration of biological and landscape diversity in sectors such as agriculture, conservation of landscapes and forest ecosystems, and action for threatened species. Such themes provide an opportunity for agroforestry. Hence PEBLS is promoting agroforestry through the combination of sectors such as agriculture and forestry at landscape levels. The 2020 Strategy is in line with the Strategic Plan for Biodiversity 2011–2020, the Aichi Biodiversity Targets, and the EU Biodiversity Strategy to 2020.

The aims of the European Convention on Landscapes (European Convention Landscapes 2017) linked to the European Council are to promote landscape protection, management and planning, and to organize European co-operation on landscape issues fulfilling the sustainability concept of the Rio Summit. This Convention takes a new approach by promoting the cultural significance and social value of all landscapes and expands concerns from simply looking at parts of our heritage, for instance monuments, buildings or species of wildlife, to a concern for the whole landscape. The Convention conveys a strong concern for awareness raising, the exchange of information and expertise. It promotes multi-disciplinary approaches and the need for a clear process of understanding and assessment of the values of landscapes. The Council of Europe, firstly through PEBLS (Pan-European Biodiversity and Landscape Strategy) and later through the European Convention on Landscapes gave a new dimension to the landscape concept

not only as a goal but as a policy means as well. European policies recognize the value of cultural landscapes and the necessity of their creative management, e.g. agroforestry systems (Sioliou and Ispikoudis 2004). Moreover, new instruments within the CAP called payment by results are tested to foster farmers collaborative approach when introducing or using a woody component at landscape level (EU 2017).

European Union policies

It was only after the Cardiff Process in June 1998, that environmental concerns were integrated into EU agricultural policies. Within the 6th Environment Action Programme (EAP 2002–2012), environment was integrated into all policies to achieve the mentioned sustainable development goals, following the signature of the previously mentioned global agreements. The 7th EAP will be guiding European environment policy until 2020 under the motto 'Living well, within the limits of our planet'.

The 7th EAP (EU 1386/2013/EU) lists nine priority objectives to be achieved by 2020. The priorities most relevant to agroforestry are: (1) to protect, conserve and enhance the Union's natural capital. This includes high value ecosystems such as wood pastures. (2) to turn the Union into a resource-efficient, green, and competitive low-carbon economy. Here agroforestry can improve resource capture and efficiency (due to multiple spatial and temporal levels) and as provider of renewable energy. (3) to safeguard the Union's citizens from environment-related pressures and risks to health and wellbeing. Here agroforestry can reduce the levels of nitrate leaching, the level of pollutants in the soil and air, and net greenhouse gas emissions (GHG). (4) to secure investment for environment and climate policy and account for the environmental costs of any societal activities, including expanding markets for environmental goods and services. The promotion of agroforestry label products would be helpful. (5) to better integrate environmental concerns into other policy areas and ensure coherence when creating new policy. As outlined in this report, agroforestry can support a holistic approach at plot, farm and landscape level fulfilling and integrating many policy areas, and (6) to help the Union address international environmental and climate challenges more effectively, as Sustainable Development Goals, as explained previously.

The key European policies related to biodiversity are the Pan-European 2020 Strategy, the Strategic Plan for Biodiversity 2011–2020 and the related Aichi Biodiversity Targets, and the *EU Biodiversity Strategy to 2020* (UNEP 2015). The EU Biodiversity Strategy to 2020 aims to halt the deterioration and achieve a measureable improvement in the status of all species and habitats covered by EU nature legislation. The strategy uses targets and actions to improve integration between and positive contributions from the agriculture, forest and fisheries sectors, for example, it is anticipated that instruments within the CAP will contribute to biodiversity targets. The strategy also aims to develop green infrastructure and to improve connectivity between Natura 2000 sites (EC 2014).

The threats to biodiversity include habitat fragmentation, intensive agriculture, land abandonment, climate change, desertification and fires. Even within agriculture, almost half of European livestock breeds are at risk of extinction due to, for example, the industrialization of farming and the global trade in agricultural products and breeding stocks. Agroforestry, which integrates agriculture and forestry and improves water quality, is a useful technology to help preservation and promote biodiversity. Agroforestry enhances biodiversity by creating different ecological niches for microorganisms, bryophytes, vascular plants, invertebrates and vertebrates. For example Rosa-García et al. (2012) reported that goats and sheep fed on different vegetation types (shrubs and herbaceous) had less health problems than when they only consume herbaceous vegetation and this modified invertebrates biodiversity at plot, farm and landscape levels.

The *Natura 2000* network, created in 1994, included areas associated with the EU Birds Directive (79/409/CEE) on the conservation of wild bird species and the EU Habitats Directive (92/43/CEE) focused on the conservation of natural habitats and the wild flora and fauna. The Birds Directive aims to protect threatened species and habitats where they feed and nest. As most threatened species are associated with specific habitats, measures are needed to preserve selected habitats. Many of these habitats are composed of, at least partially, woody vegetation, and therefore, often include agroforestry practices. Each member state of the EU has to identify the important areas and

establish management plans combining long-term conservation and socio-economical activities. Across the EU, the Natura 2000 network accounts for 27,200 protected areas covering more than one hundred million hectares (788,000 ha terrestrial) of the EU territory (18.2%). The network consists of the so called 'special protection areas' (SPA) designated to protect endangered bird species and 'sites of Community importance' (SCI) established for protection of habitat types and species listed in the Habitats Directive. However it is argued that the current implementation will need to be strengthened if the union intends to achieve its 2020 biodiversity targets.

The birds and habitat directives are linked to the "conditionality" or "cross-compliance" mechanism in the CAP Pillar I, supported by the agri-environmental measures within Pillar II, and are very important for protecting agricultural areas of high biodiversity, which are under a constant pressure and include for instance Fennoscandian wooded pastures and meadows, High Nature Value farmland (dehesas, montados) and other extensive systems, and natural and semi-natural grasslands. Key farmland habitats and features that require preservation and maintenance include: hedgerows, copses or small woodlands, single trees and bushes in fields, trees and bushes traditionally used for pollarding and coppicing, large veteran trees in agricultural areas, orchards, olive groves, and nut groves with old mature trees (EC 2014), most of them linked to the presence of woody vegetation and therefore to agroforestry practices. Abandonment of extensive traditional farming practices is the most important pressure on key farmland habitats and species of Community interest, together with the intensification of other practices (EU guidance document Farming for Natura 2000). Nature 2000 is targeted in the 53% of Agroforestry measure of the Rural Development Programmes of the Common Agrarian Policy (Mosquera-Losada et al. 2016).

The Natura 2000 sites are supported by Pillar I of the CAP (the European Agricultural Guarantee Fund (EAGF)) and Pillar II of the CAP (the European Agricultural Fund for Rural Development (EAFRD)). However the Natura 2000 sites are also supported through the Programme for the Environment and Climate Action (LIFE). Other EU funds available are the European Structural Funds: Regional Development Fund (ERDF), Cohesion Fund (CF) and Social Fund (ESF) that are now integrated. Payments for Ecosystem Services (PES) schemes can also provide an incentive for the conservation and restoration of farmland biodiversity and habitats in order to safeguard (or potentially increase) the provision of the ecosystem services it provides.

Therefore several measures are established such as the development of biodiversity indicators and the promotion of agri-environmental measures within the CAP to establish a system of direct payments for environmental services, e.g. for promotion of grazing with native breeds or establishing agroforestry systems (measure 222 of CAP period 2007-2013 or measure 8.2 linked to CAP 2014-2020).

The broad objectives of the *European Strategy on Sustainable Development* cut across many sectors including agriculture and forestry. One of the sustainable development objectives is to manage natural resources in a responsible way, to protect habitats and ecosystems, and to halt the loss and then promote biodiversity, all them linked with agroforestry as it was mentioned in previous sections.

The goal of the *European Climate Change Programme* (ECCP), launched in 2000, was to develop an EU strategy to implement the Kyoto Protocol. It comprised policy measures to reduce greenhouse gas emissions and improve energy efficiency. Even though the EU-28 reduced GHG emissions by 24% between 1990 and 2012, new policies are needed to meet the target of a 40% reduction below levels in 1990 by 2030 (EU 2016). Agroforestry can contribute to carbon sequestration, the reduction in the increase in the atmospheric concentration of greenhouse gases, and adaptation to climate change (Sharrow and Ismail 2004; Lal 2004; Mosquera-Losada et al. 2011; Aertsens et al. 2013; Upson et al. 2016). Compared to other agricultural options, agroforestry will generally increase carbon storage per unit of area (Dixon et al. 1994; Nair et al. 2008; Upson et al. 2016). In addition, agroforestry is anticipated to reduce soil erosion (Palma et al. 2007) and reduce the airborne particulate matter in the air to allow a better breathing of healthy air (Silli et al. 2015).

Agroforestry is mentioned several times as an agricultural activity in the last Intergovernmental Panel on Climate Change assessment (Smith et al. 2014), which defines agroforestry as an integrated system together with the mixed systems and explains "AFOLU (agriculture, forestry and other land uses) mitigation measures linked to increases in food

production (i.e. agroforestry, or integrated systems) can increase food availability and access especially at the local level". There are several types of agroforestry practices that can contribute to mitigate climate change as recognized land use, land-use change and forestry (LULUCF) activities. The first approach to mitigating climate change is related with Article 3, paragraph 3 of the Kyoto Protocol by strengthening protection against natural disturbances such as fire, pests, and storms, where agroforestry practices are able to reduce the possibility to reclassify areas declared as AR to D that is thereafter permanent for the entire commitment period. Silvopasture in forest lands and silvoarable in arable lands are the best practices to avoid this conversion. Forest grazing is the most sustainable and cheapest tool to clear understory within the forest as the biomass is converted into animal products and at the same time fire risk is reduced (RAPCA 2017). Moreover silvoarable practices, e.g. the combination of annual arable crops during the first years of a tree plantation, when the tree canopy is relatively small, can force trees to develop deeper root systems which makes the trees better anchored and therefore more resilient to natural disturbances like storms, strong winds, flooding or important snow events (Rigueiro-Rodríguez et al. 2009).

The second approach to mitigating climate change is related with Article 3 paragraph 4. It deals with different land management practices like (1) Forest management (FM: system of practices for stewardship and use of forest land including plantations and natural forests), not including the areas integrated in AR or D, (2) Cropland Management (CM: system of practices on land on which agricultural crops are grown, and on land that is set aside or temporarily not being used for crop production), (3) Grazing land management (GM: system of practices of land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced) and (4) Revegetation (RV: is defined as a direct, human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 hectares and does not meet the definitions of afforestation and reforestation). The EU has already determined the activities related with these different lands and the management that should be taken into account (Decision 529/2013/EU) as shown in Table 2.

Agroforestry has been identified as an indicative measure that may be included in the information on LULUCF actions submitted pursuant to Article 10(2)(d) as part of "Cropland Management" (CM), therefore identifying agroforestry as agricultural land and an agricultural activity (Table 2). Other types of tentative measures included by the EU are those linked to grazing land management and pasture improvement. Grassland management and grassland improvement measures identified by the EU include increasing productivity, nutrient management, the introduction of deep rooted species (also related to agroforestry as productivity and nutrient management is enhanced by the inclusion of deeply-rooted woody vegetation) (Rigueiro-Rodríguez et al. 2009). The forest activities promoted by agroforestry practices (Table 2) include those related with soil carbon conservation and the increasing agricultural use of forest land (e.g. increasing harvest wood forests and production in existing forests). Moreover, preventing deforestation and strengthening protection against natural disturbances such as fire, pest and storms can be enhanced by agroforestry. The use of wood products can also be promoted if trees are located on arable land, which links to the bioeconomy if, for example, pruned branches are used for compost production.

The *EU Bioeconomy Strategy* (EC 2012) is described in a document entitled 'Innovating for Sustainable Growth: A Bioeconomy for Europe'. It proposes a comprehensive approach to address the ecological, environmental, energy, food supply and natural resource challenges faced by Europe and the world. It aims to improve the knowledge base and foster innovation to achieve productivity increases, while ensuring sustainable resource use and alleviating stress on the environment. A successful bioeconomy has the potential to create economic growth and jobs, to reduce fossil fuel dependence, and to improve economic and environmental sustainability. A key bioeconomy concept is the circular economy where the "waste" from the creation of one product should be used as raw material for a second product. The strategy will thus support resource efficiency, sustainable use of natural resources, protection of biodiversity and habitats, as well as provision of ecosystem services. Agroforestry can contribute to the circular economy as a primary and renewable source of products including food, wood for timber, and biomass energy. Agroforestry can also support the

Table 2 EU indicative measures that may be included in the information on LULUCF actions submitted pursuant to Article 10(2) (d) (Decision 529/2013/EU) that can relate to agroforestry

Measures related to	Examples
Cropland management	Agroforestry
Grazing management and pasture improvement	Preventing grassland to cropland
	conversion to native vegetation
	Increasing productivity
	Improving nutrient management
	Introducing more appropriate species, in particular deep rooted species
Forest activities	Afforestation and reforestation
	Conservation of C in existing forest
	Enhancing production in existing forests
	Increasing harvested wood products
	Enhancing forest management (optimize species composition, tending, thinning and soil conservation)
Preventing deforestation	
Strengthening protection against natural disturbances such as fire, pest and storms	
Substitution GHG intensive energy feedstock and materials with harvested wood products	

Bioeconomy Strategy by enabling increased carbon sequestration on agricultural land.

The *European Forestry Strategy* (EU 2013a) aims to ensure that the multifunctional potential of EU forests is managed in a sustainable and balanced way, enabling the "correct" functioning of ecosystem services. It highlights the contribution of forests to employment, well-being, the environment, and rural development. The Forest Strategy from 2013 specifically mentioned agroforestry for the first time. It states: "Member States should use the opportunities given in the new Rural Development Regulation and prioritise investments in: (…) achieving nature and biodiversity objectives; adapting to climate change; conserving genetic resources; forest protection and information; and creating new woodland and agroforestry systems".

A recent development has been an increased awareness of how trees can also contribute to well-being. For example the *Social Farming and Rural Development policy* (ENRD 2010) has highlighted how kitchen gardens (which often include fruit trees) can enhance public health and social inclusion. Again this demonstrates the important role that agroforestry has to play.

In September 2016, 20 years after the 1996 Cork Declaration in relation to the EU and the environment, the "Cork 2.0: European Conference on Rural Development" was held (EU 2016). This was attended by different policy bodies including the European Agroforestry Federation (EURAF). Discussions led to the development of the Cork Declaration 2.0 which highlights the participation of farmers and foresters as key actors to develop a sustainable agriculture, the recognition of traditional heritage agricultural systems, the inclusion of forestry within the EU agrarian policy, the need of enhancing ecosystem services from agriculture, reducing the impact of climate change (mitigation and adaptation) and the importance of integrated systems such as agroforestry. Agroforestry can contribute to any of the economic, social and environment aspects mentioned in the Cork Declaration.

Current implementation or agroforestry within the CAP

CAP is the main driver for agricultural and forest use management across 28 countries of Europe based on a document that applies for periods of 7 years. The CAP

of the 2014–2020 period is paid mainly addressing sustainable productivity (Pillar I, fully founded by the European Union) and environment (Pillar II, cofounded by the member states) and based on plot payments following the Regulation 1307/2013 (EU 2013b). Pillar I payments are done in arable, permanent grasslands and permanent crops. Agroforestry practices represent less than 0.1, 10% and 0.1% of the potential areas allocated to arable, permanent grassland and permanent crops, respectively (Mosquera-Losada et al. 2011). Therefore the promotion of agroforestry in these lands will definitively bring many ecosystem benefits from current intensive farm systems. Main limitations to expand the use of agroforestry practices in arable lands are related with the tree density limitation up to 100 trees per hectare, that does not consider the higher initial tree density needs to ensure adequate tree production when harvesting the stand. Main limitations to expand the use of agroforestry practices in permanent grasslands is associated with the same limitation than 100 trees per hectare but also, in those countries that implement the pro-rata system with the reduction of payments based on the presence of woody vegetation in the grassland plots. In both types of lands, arable and permanent grasslands, farmers destroy woody perennials to get paid by the CAP Pillar I. On the contrary, there are no limitations to foster agroforestry in permanent grasslands, but the inertia coming from years of doing intensification as the adequate land management prevents from the implementation, in spite of the benefits that agroforestry has in these plots. A possible solution will be to allow full Pillar I payments if a management plan is developed that will also ensure greening payment, the thirty percent of the Pillar I payment if activities dealing with agricultural practices beneficial for the climate and the environment are carried out (Regulation 1307/2013). Pillar II has 27 measures that can be considered to foster agroforestry as they promote the integration of woody vegetation, however not recognized as such as agroforestry. The main measure enhancing agroforestry is the agrienvironment measure (Measure 10.1) mainly associated with the promotion of silvoarable practices. However agroforestry has its own measure (Measure 8.2) that has been applied by 32 regions out of the 118 regions of Europe, meaning a huge increase with respect to the period 20107–2013. However, the main problem with the agroforestry measure is the loss of Pillar I payments if the agroforestry measure is up taken in many cases due to the initial tree density they have. Improvement of agroforestry extent in Europe should be based in management a plan that ensures final tree densities of 100 trees per hectare, independently of the initial tree density. Moreover, the recognition of all agroforestry practices named as silvopasture, silvoarable, hedgerows and riparian buffer strips, homegardens and forest farming should be clearly stated for the whole CAP. Due to the huge potential benefits that the different agroforestry practices implementation has in Europe an Agroforestry strategy should be delineated as already happen in different countries such as France, USA or India.

Current CAP also tries to foster innovation, as an acknowledgement of the reduced implementation of sustainable techniques in farming systems at European level, in spite of the huge research advance. The main body carrying out this activity is the EIP–AGRI that aims at integrating the huge European Research Programme (H2020) with Innovation based on the involvement of different stakeholders bottom-up strategies design and multiactor approaches. On this sense, the European Innovation Partnership (EIP–AGRI) has hosted the Focus Group on Agroforestry where policy makers, farmers and researchers made an effort to delineate the main agroforestry current activities and drawbacks to be fostered across Europe. The H2020 program has recently funded AFINET (Agroforestry Innovation Network) with 2 Million Euros that will work with farmers from 9 European regions trying to identify the main farmer technical limitations to approach agroforestry and develop materials to overcome the current lack of knowledge of agroforestry practices among farmers.

Conclusions

There is a global and European recognition of the role that agroforestry can play to provide products but also to deliver highly important ecosystem services. However, the promotion of agroforestry practices at European level is still not well addressed by the Common Agricultural Policy. The clear identification of agroforestry practices, the link of management plans to establish agroforestry pursuing a final eligible tree density for the Pillar I payments should be addressed as initial steps to foster agroforestry in

Europe. There is a lack of knowledge transfer that promotes agroforestry at field level, which should be approached by using stakeholder integration within the policy development as it is currently done by the EIP-Agri.

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