TESE DE DOUTORAMENTO

INCREASING AGRICULTURE SUSTAINABILITY IN EUROPE: DRIVING FACTORS FOR AGROFORESTRY IMPLEMENTATION

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Increasing agriculture sustainability in Europe: driving factors for agroforestry implementation

Dna. María Rosa Mosquera Losada, e
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To all farmers and foresters,
those who feed the world population
and manage our landscape.
Those are the stewards of Mother Earth.

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RESUMO

Europa caracterízase por amosar unha paisaxe esencialmente rural, onde o 40 % da superficie da Unión Europea é agrícola e o 42 % é forestal (Eurostat 2016). Sen embargo nas últimas décadas vense producindo un abandono do rural e unha migración ás cidades (Renwick et al. 2013; Pointereau 2008; Keenleyside et al. 2010) por motivacións varias, entre elas a reducida rendibilidade da agricultura (Breustedt and Glauben 2007). Esto tivo consecuencias máis alá da economía local (García-Ruiz e Lana-Renault 2011; Moreira e Russo 2007). Para frear este abandono das zonas rurais, deben ser fomentados tanto o apoio privado como o público (Olper et al. 2014). Os sistemas agroforestais son unha das actividades que poden contribuír ao desenvolvemento rural, proporcionando emprego, para fixar e atraer poboación, e beneficios dun xeito sustentable (Mercer et al. 2014; Valdivia et al. 2009; Rancane et al. 2014). A agrosilvicultura foi un uso tradicional da terra en Europa dende os inicios da civilización e incidiu de forma importante nos distintos modelos de paisaxe. Sen embargo, moitos destes sistemas foron desaparecendo por mor dos cambios económicos e sociais (abandono da terra, urbanización e intensificación agraria). Dende a revolución industrial estes sistemas foron pouco a pouco substituídos por monocultivos agrícolas ou forestais, pero dende a década dos 90 a agrosilvicultura colleu pulo de novo como sistema de uso sustentable da terra e xorden iniciativas europeas para fomentar a súa expansión (Smith 2010). Mais ese espallamento, aínda que hai exemplos de éxito, foi limitado (Pisanelli et al. 2014; Luske et al. 2016). De acordo cun estudo recente de den Herder et al. (2017) a superficie total de sistemas agroforestais na UE-27 é de 15,4 millóns de hectáreas, é dicir un 3,6 % do seu territorio ou un 8,8 % da superficie agraria, considerando unicamente os sistemas con árbores, sen incluir os que levan arbustos como elemento leñoso, xa que de considerar éstos acádanse preto dos 20 millóns de hectáreas. En concreto, o silvopastoreo é a práctica máis importante en Europa (Rodríguez-Rigueiro et al. 2021). A agrosilvicultura é un uso de solo que pode ser aplicado en situacións moi diversas: terreo forestal, agrícola (arable, pastos permanentes e cultivos permanentes) e incluso en terreo urbano e periurbano (Mosquera-Losada et al. 2016a).

Os sistemas agroforestais implican a integración deliberada dun compoñente leñoso, arbóreo ou arbustivo, cunha produción agrícola ou aproveitamento pascícola. Asócianse a eles servizos ecosistémicos e a optimización do aproveitamento dos recursos nos subsistemas agrícola e forestal que os constitúen (Rigueiro-Rodríguez et al. 2009; FAO 2014). A agrosilvicultura permite aliñar e incrementar a produción ao mesmo tempo que salvagardan os servicios ecosistémicos (Jose 2009). Fagerholm et al. (2016) aporta unha síntese sistemática dos bens e servicios ecosistémicos proporcionados polos sistemas agroforestais en Europa, identificando os seguintes: (i) provisión: recursos xenéticos, alimento, combustible, fibras, (ii) regulación: ciclo e calidade da auga, proteción fronte a tormentas, control da erosión, prevención fronte a incendios, control biolóxico, polinización e regulación do clima, (iii) cultural: valor estético, recreo e ecoturismo, valores de patrimonio cultural, sentido de pertenza, relacións sociais e coñecemento, e (iv) apoio: provisión de hábitats e mellora da biodiversidade, ciclo dos nutrientes, e formación do solo.

As investigacións dos últimos anos demostran os grandes beneficios que aportan os sistemas agroforestais, aínda que son prácticas descoñecidas por moitos agricultores. Dada a situación

actual, na que se considera necesario proporcionar seguridade alimentaria fronte ao aumento da poboación mundial e loitar contra o cambio climático, presentándose a bioeconomía como a vía inequívoca para un desenvolvemento económico que teña en conta a sustentabilidade dos recursos naturais, os sistemas agroforestais se presentan como una alternativa sostible con futuro.

Por outra banda, as políticas adoptadas condicionan en gran medida as alternativas ás que poden optar os agricultores e silvicultores e deberían ser un instrumento crucial para fomentar o desenvolvemento e extensión dos sistemas agroforestais.

Para poder intervir e definir políticas e actividades de educación e formación que contribúan a fomentar o uso de sistemas agroforestais por parte de agricultores e/ou silvicultores é necesario un diagnóstico da situación actual, pois para que as medidas adoptadas sexan efectivas é importante analizar primeiro as experiencias dos agricultores e/ou silvicultores e coñecer como entenden eles as súas actividades e contextos (Boonstra et al. 2011; Bernués et al. 2016). É por tanto necesario estudar tanto as motivacións como as barreiras que levan aos agricultores e/ou silvicultores a establecer ou non sistemas agroforestais fronte a unha agricultura e silvicultura convencionais. Esta tese busca afondar no coñecemento das razón dos agricultores e/ou silvicultores europeos para establecer sistemas agroforestais e tamén analizar como afectan as políticas existentes en Europa ao uso e expansión dos mesmos. Os obxectivos da presente tese son por tanto:

1. Identificar as motivacións que teñen os agricultores e/ou silvicultores para optar polo uso dunha agricultura ou silvicultura convencionais ou polos sistemas agroforestais, e cales son as barreiras que atopan para decantarse por estes últimos.
2. Analizar con expertos coñecedores dos sistemas agroforestais cales son as motivacións para establecelos.
3. Identificar cales son as principais políticas europeas que inflúen na preferencia polos sistemas agroforestais como forma de uso do terreo agroforestal.

Para poder alcanzar eses obxectivos, a tese aplica distintas metodoloxías en base a cada un deles. Na identificación de motivacións e barreiras percibidas polos agricultores aplícase a metodoloxía da Teoría Fundamentada (Grounded Theory) de Glaser e Strauss (1967), metodoloxía cualitativa de investigación científica, identificada como unha ‘aproximación indutiva na cal a inmersión nos datos sirve de punto de partida do desenvolvemento dunha teoría sobre un fenómeno’ (Guillemette 2006), que tende a ‘xeneralizar na dirección das ideas teóricas, subliñando o desenvolvemento de teorías máis que a proba dunha teoría’ (Hunt e Ropo 1995). Para elo leváronse a cabo entrevistas a agricultores e silvicultores en varios países europeos, cun mínimo de 8 entrevistas a agricultores que utilizan agricultura convencional e outras 8 a agricultores ou silvicultores que empregan sistemas agroforestais. Realizáronse un total de 183 entrevistas en 8 países, concretamente España, Italia, Grecia, Portugal, Francia, Alemaña, Reino Unido e Hungría. A análise destas entrevistas é o obxectivo principal desta tese. Os sistemas estudados inclúen sistemas agroforestais de alto valor natural e cultural, sistemas silvoarables, sistemas con alto valor do arboredo, e sistemas silvopastorais, así como usos do terreo agrícola ou forestal convencional. A intención das entrevistas foi levar a cabo unha análise temática para afrontar a pregunta da investigación: ‘por que son aceptados ou non os sistemas agroforestais?’. O obxectivo era valorar que factores favorecen ou rexeitan a adopción dos sistemas agroforestais polos agricultores e/ou silvicultores europeos, comprender o coñecemento que teñen deses sistemas e identificar as razóns polas que eliminaron as árbores das súas parcelas.

A visión cualitativa dos agricultores foi combinada con aportacións cuantitativas de expertos na rexión mediterránea. Para estudiar as motivacións identificadas por expertos en sistemas agroforestais levouse a cabo unha simulación baseada no Proceso Analítico en Red (Analytic Network Process ANP) desenvolvido por Thomas L. Saaty (1996), trátase dunha análise de decisión multi-criterio, a diferenza da análise indutiva das entrevistas. Realízase en base a sucesivos cuestionarios dirixidos a investigadores expertos en sistemas agroforestais. Este método permite realizar unha análise dos diferentes criterios, das súas influencias e das valoracións dos expertos, de maneira que se poden extraer conclusión teóricas e metodolóxicas para resolver este tipo de problemas. O deseño dos cuestionarios resulta dun proceso iterativo con varias consultas aos expertos. A decisión de aplicar un sistema agroforestal depende de consideracións económicas, sociais e medioambientais con complexas implicacións de posibles beneficios, costes, oportunidades e riscos, que son dificilmente avaliables de forma cualitativa. O uso do modelo ANP nesta tese axuda a solucionar esta complexidade ao través dun escenario de decisión centrado nunha granxa ´típica'.

Para contextualizar o marco político procédese a realizar unha revisión das diferentes políticas e estratexias que afectan directa ou indirectamente ao uso dos sistemas agroforestais, e como estes poden contribuír aos obxectivos que pretenden as mesmas. En particular a tese céntrase na Política Agraria Común (PAC), por ser a política de maior impacto na agricultura e o desenvolvemento rural. A análise baséase nunha revisión bibliográfica da regulación europea da PAC para o Pilar I e Pilar II cos Programas de Desenvolvemento Rural para o período 2014-2020, para analizar como é promovida no marco da PAC (2014-2020) a presenza e manexo da vexetación leñosa máis aló da medida específica de sistemas agroforestais incluída inicialmente na PAC 2007-2013 no Pillar II.

Os sistemas agroforestais contribúen ao desenvolvemento e logro de obxectivos dun gran número de estratexias e políticas, tanto a nivel global (as Declaracións de Orlando e Lugo, a Axenda 2030 e os Obxectivos de Desenvolvemento Sostible, ODS), como a nivel europeo (a Estratexia da Biodiversidade, a Estratexia Forestal, a Estratexia de Bioeconomía, o Pacto Verde, a Declaración de Cork 2.0 e a Política Agraria Común PAC, entre outras). De entre tódalas políticas europeas sen dúbida a PAC foi a de maior influencia na agricultura e sustentabilidade na UE.

O presuposto da PAC foise incrementando en termos absolutos dende os primeiros anos ata o 1992, permanecendo relativamente estable dende entón (EP 2021). Por contra, a porcentaxe de gasto da PAC en relación ao presuposto total da Unión Europea (UE) foi decrecendo, dende o 74 % no 1985 ata o 37,5 % no 2019, e incluso o 28,5 % para o período 2021-2027, a pesares das sucesivas ampliacións da UE, por mor das reformas da PAC e o maior número de políticas da UE (EC 2020b).

Para poder recibir os subsidios de calquera dos pilares da PAC é indispensable o cumprimento de certas regras, coñecidas como a condicionalidade, que se refiren ás condición ecolóxicas e ambientais das axudas, requisitos mínimos en sustentabilidade, como poden ser calidade da auga ou benestar animal. Os condicionantes no Pilar I están asociados ao uso da terra en pastos permanentes, cultivos permanentes e arables. Os requisitos para recibir pagos do Pilar II son establecidos por cada Estado Membro en función dos seus intereses produtivos e medioambientais, estando definidos no Pilar II nos Programas de Desenvolvemento Rural nacionais e rexionais. A futura PAC 2021-2028 dará maior responsabilidade aos Estados

Membro sobre a elixibilidade e aplicación da PAC, obrigando a que os pagos estean ligados a resultados (Mosquera-Losada et al. 2019c).

A tese identifica como os factores clave para o uso da agrosilvicultura a tradición na familia ou na rexión, a diversificación dos produtos que se poden obter e o coñecemento de experiencias exitosas. A diversificación de produtos está ligada a un menor risco na produción fronte a cambios no mercado ou a unha climatoloxía adversa. En cambio, os factores que favorecen unha agricultura convencional son a tradición, como no caso anterior, mais outros como a falta de coñecemento sobre sistemas agroforestais ou a simplicidade da agricultura convencional.

De todos modos, outros factores que afectan á decisión foron a viabilidade económica, a existencia de subsidios, o tempo de dedicación necesario e a complexidade da xestión, a calidade do solo, así como a idade do agricultor e a propiedade da terra, xa que a plantación de árbores limita os futuros usos posibles da parcela. Os agricultores en xeral optan por plantar árbores en terreos marxinais, onde a agricultura convencional é difícil ou non rendible. Outras razóns identificadas para practicar agrosilvicultura foron o benestar animal, a mellora do medioambiente, a calidade da paisaxe e a calidade de vida. Ademais, os agricultores e silvicultores que tiñan ingresos por outros traballos, amosáronse más dispostos a practicar a agrosilvicultura.

Tamén se identificou un coñecemento limitado sobre agrosilvicultura entre os agricultores ou propietarios forestais, polo que para fomentar o uso dos sistemas agroforestais é preciso mellorar a educación e formación dos agricultores e silvicultures sobre os beneficios dos mesmos, especialmente a través de exemplos de casos de éxito. De feito observouse que, se se presentan ditos exemplos, os agricultores amosan un crecente interese e unha maior disposición a aplicalos. Neste eido, os servicios de extensión agraria e forestal xogan un papel crucial na transferencia do coñecemento acadado nos últimos avances.

A existencia de axudas tamén favorece que os agricultores xestionen o territorio de certa maneira. Algúns agricultores desta investigación recibiron axudas para estas prácticas agroforestais, mentres que a maior parte deles descoñecían a existencia das mesmas, que en calquera caso son limitadas no Pilar II da PAC e comprometen a elixibilidade para o Pilar I. Os regulamentos en xeral son vistos polos agricultores máis como un impedimento que como unha motivación para sumarse á agrosilvicultura, e referímonos tanto aos que adoptan estas prácticas coma aos que non as aplican.

Así mesmo hai unha necesidade de aumentar a concienciación entre os consumidores, para que amosen unha prioridade por produtos derivados da agrosilvicultura a pesar dos prezos algo máis elevados que teñen nalgúns casos, actitude que actuará como incentivo para os agricultores.

Os expertos en sistemas agroforestais percibiron como beneficios medioambientais máis importantes a menor necesidade de productos como insecticidas, funxicidas, herbicidas e fertilizantes, a mellora da calidade da auga e a mellor regulación da circulación das augas superficiais. Ao efecto positivo sobre da biodiversidade, da paisaxe, da conservación do solo e do benestar animal asignóuselle unha prioridade inferior. Entre os beneficios económicos, os máis relevantes foi o menor risco de negocio, dada a diversificación de produtos e a súa maior calidade, coincidindo coas razóns indicadas polos agricultores. O aumento dos custos de recursos humanos e a competencia entre cultivos, arboredo e animais foron identificados como factores negativos significativos. As principais oportunidades identificadas foron a existencia de axudas económicas e a axuda técnica dos servizos de extensión. Os riscos principais detectados son as escasas oportunidades de mercado e a falta de subsidios.

Avaliar o impacto da PAC, e en particular das medidas agroforestais, no territorio europeo é difícil por varias razón como son: (i) a capacidade dos países para escoller entre diferentes opción na PAC, (ii) a variedade de opcións en canto ao período de aplicación, que adoita ser de 7 anos, (iii) a diferente situación ambiental e socioeconómica dos Estados Membro, e (iv) o número de países que aplican a PAC, xa que nos últimos anos foron uníndose países con diferentes grados de adaptación as políticas europeas.

Unha das dificultades para expandir a agrosilvicultura a escala europea foi a falta de acordo na súa definición. A PAC do período 2007-2013 incluía unicamente arboredo como compoñente leñoso, mentres que a inclusión tamén de arbustos na PAC 2014-2020 facilita a adaptación dos sistemas agrícolas en función das distintas situacións dos Estados Membro. No Pilar I é difícil identificar as diferentes prácticas agroforestais (silvopastoreo, silvoarable, sebes vivas, barreiras para frear o vento e zonas riparias, aproveitamento múltiple forestal e hortos), xa que son normalmente recoñecidos por nomes locais (hortos pastoreados, pastos baixo arboredo, ‘dehesa’, ‘montado’, sebeiros) pero non identificados como sistemas agroforestais.

O fomento do compoñente leñoso en Europa pódese apreciar en diferentes seccións da PAC ligadas ao Pilar I (pagos directos) e Pilar II (programas de desenvolvemento rural), aínda que a agrosilvicultura non está explicitamente recoñecida na PAC salvo na Medida 8.2 ‘Establecemento de sistemas agroforestais’ do Pilar II. A Comisión Europea recoñeceu no ano 2005 o valor social e medioambiental dos sistemas agroforestais e a medida específica de axuda ao establecemento dos mesmo (M222) foi introducida na PAC 2007-2013 e mellorada na PAC 2014-2020 (M8.2), e previsiblemente continuarán as melloras nos vindeiros anos. Estas medidas que afectan aos terreos forestais tiveron unha repercusión limitada en tódolos países europeos, principalmente debido á Medida 8.1 ‘Plantacións forestais e creación de bosques’, xa que simplemente coas plantacións os propietarios obteñen axudas por máis de 15 anos, practicando agrosilvicultura ou non, mentres que coa medida 8.2 reciben as axudas por menor tempo.

As limitacións observadas na PAC en canto ao fomento da agrosilvicultura en terreos arables foron: (a) a cuberta da vexetación leñosa está limitada ao 10 % na PAC 2014-2020, mentres que na anterior o límite establecíase no 5 %, (b) a densidade do arboredo está limitada a 100 pés ha^{-1}, mentres que na anterior non se podían superar os 50 pés ha^{-1}, (c) as sebes máis altas de 2 m non soen ser elixibles, incluso cando están protexidas. Estas limitacións conduciron á eliminación de árbores e arbustos en toda Europa, na meirande parte en pequenas parcelas para que puideran ser elixibles das axudas do Pilar I.

As prácticas silvoarables ou cultivo en liñas, vinculadas aos cultivos permanentes, ben sexa de árbores froiteiras ou cultivos arbustivos, son totalmente elixibles na PAC 2014-2020, mais non son explicitamente mencionadas ou fomentadas como agrosilvicultura.

En canto ás pradeiras permanentes, a vexetación leñosa foi protexida en certo nivel baixo as chamadas Prácticas Locais Establecidas (PLE) definidas libremente nos Programas de Desenvolvemento Rural nacionais ou rexionais. Na PAC tamén se identificaban como elixibles as árbores pastoreadas, pero coa limitación de que o gando tiña que alimentarse directamente delas, non dos froitos que pudieran caer. Esta limitación mudou coa directiva OMNIBUS durante o período de funcionamento da PAC 2014-2020.

Os sistemas agroforestais, conformados tanto por arboredo como por arbustos, permiten adaptar as paisaxes agrarias ao cambio climático, mitigando algúns dos seus efectos negativos, cando menos na súa intensidade. A agrosilvicultura preséntase tamén como unha ferramenta para producir alimento de forma sustentable e mellorar a resiliencia dos ecosistemas fronte a amenazas como os incendios forestais ou brotes de enfermidades. Todos estes beneficios non foron ata o de agora suficientemente recoñecidos polas políticas públicas fomentando o seu espallamento, a pesares de que os sistemas agroforestais poden contribuír a unha gran cantidade de obxectivos globais e europeos. De todos modos hai unha recente tendencia ao seu

reconecemento e fomento. De feito, o capital natural é cada vez máis valorado tanto por gobernos e institucións como polo sector privado. Mentres que a industria ten que adaptarse á bioeconomía circular, demandando en orixe materias primas ou subprodutos sustentables, a Unión Europea ten que entender a realidade dos agricultores e silvicultores para definir e aplicar políticas eficaces, fomentando que xestionen as súas terras de certo modo.

Dada a gran variedade de produtos que se poden obter coas diferentes combinacións nos sistemas agroforestais, aliñando produción múltiple con sustentabilidade e servicios ecosistémicos, a agrosilvicultura ten un gran potencial para proporcionar materias primas e subprodutos que son cruciais para despregar unha bioeconomía circular que permita á sociedade vivir dentro dos límites do planeta.

PALABRAS CHAVE: motivacións, políticas, actores, resiliencia, uso da terra, cambio climático

TABLE OF CONTENTS

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DE COMPOSTELA

1 INTRODUCTION

Europe is characterized by a predominantly rural landscape (Eurostat 2016). In 2013, there were 10.8 million farms across the European Union (EU), working 174.4 million hectares of land (Utilised Agricultural Area or UAA), i.e. 40% of the total land area of the EU28, while the forested area of the EU is slowly increasing and covers a slightly greater proportion of the land than is used for agriculture (42%) as highlights Eurostat (2016). However, over the last few decades, there has been a clear pattern of rural land abandonment and migration of people from rural to urban areas (Renwick et al. 2013; Pointereau 2008; Keenleyside et al. 2010). The motivation for this movement varies among regions but a common factor is related to agricultural reduced profitability (Breustedt and Glauben 2007). The number of farmers in Europe is declining and their average age is going up (EC 2015). Maintaining agricultural activities, particularly in low productive areas, becomes difficult and agricultural land is abandoned, having consequences beyond the local economy (García-Ruiz and Lana-Renault 2011; Moreira and Russo 2007).

To stop abandonment of rural areas, public and private support needs to be enhanced (Olper et al. 2014). Agroforestry is one of the activities that could help to stimulate rural areas by providing additional employment and financial revenue in a sustainable way (Mercer et al. 2014; Valdivia et al. 2009; Rancane et al. 2014). Agroforestry (AF) is a *'climate-smart agriculture (CSA) practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions'* (Mosquera-Losada et al. 2018). They provide ecosystem services and the optimization of the resources in both agricultural and forest subsystems (Rigueiro-Rodríguez et al. 2009; FAO 2014).

Moreover, one of the main problems along the years was the lack of a clear definition of what agroforestry is, which affects to the real implementation. The recognition of agroforestry as a sustainable land use is essential for farmers to move on specific questions such as techniques to be applied but it is also important for policy makers to foster the deployment of agroforestry (Mosquera-Losada 2018b) based on the ecosystem services that agroforestry provides.

Agroforestry is defined nowadays as a '*woody perennial (trees and/or shrubs) and an agricultural product always provided by the lower storey'* as part of the CAP (Mosquera-Losada 2018b), being a type of land use that can be applied in all types of land cover such as forest and agriculture (arable land, permanent grassland and permanent crop) but also urban and peri-urban areas (Mosquera-Losada et al. 2016a) (Table 1). These agroforestry practices conform agroforestry systems when the farm scale is used.

Mosquera-Losada et al. (2016), describes five main types of agroforestry practices:

Silvopasture - Combining woody with forage and animal production. It comprises forest or woodland grazing and pastoral land with hedgerows, copses, isolated/scattered trees or trees in lines or belts.

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, copses, isolated/scattered trees, hedges and line belts design.

Riparian buffer strips - Lines of natural or planted perennial vegetation (trees/shrubs) bordering croplands/pastures to protect livestock, crops, and/or soil and water quality. They can be combined with arable lands (silvoarable) or grasslands (silvopasture).

Forest farming - Forested areas used for production or harvest of natural standing speciality crops for medicinal, ornamental or culinary uses, including those integrating forest and agricultural lands.

Homegardens or kitchengardens - Combining trees/shrubs with vegetable production in urban areas.

Table 1. Agroforestry practices linked to main farm types and land use (agriculture, forest or peri-urban). Source: Mosquera-Losada et al. (2016).

Land use	Agroforestry practice	Common name	Brief description
AGRICULTURE	Silvopasture	Wood pasture and parkland	Typically areas of widely-spaced trees that are also used for forage and animal production
		Meadow orchards	This practice includes fruit orchards, shrubs which are grazed or sown with pastures, but also olive groves and vineyards
	Silvoarable	Hedgerows and windbreak systems	Here the woody components are planted to provide shelter, shade, or parcel demarcation to a crop and/or livestock production system
		Alley-cropping systems	Widely spaced woody perennials inter-cropped with annual or perennial crops. It comprises alley cropping, scattered trees and orchards and line belts within the plots. These practices are sometimes found only during the first few years of the plantation
	Riparian buffer strips	Riparian buffer strips	Areas of tree and shrubs allowed to establish croplands/pastures and water sources such as streams, lakes, wetlands, and ponds to protect water quality, can be identified as silvoarable or silvopasture
FOREST	Silvopasture	Forest grazing	Forested areas with the understory grazed
	Forest farming	Forest farming	Forested areas used for production or harvest of naturally standing speciality crops for medicinal, ornamental or culinary uses
URBAN AND PERIURBAN	Homegardens	Homegardens	Combining trees/shrubs with vegetable production usually associated with peri-urban or urban areas

A common mistake in the past has been not considering shrubs, instead of trees, as part of agroforestry, when shrubs are combined with pasture or arable crops in spite of being accepted by the main the world agroforestry associations (FAO 2015; ICRAF 2017). In line with that, a problem is the lack of a harmonized of a tree definition among countries, woody component above 2 vs 5 meters, height which is also influenced by the tress/shrub species, the site conditions and the felling method (e.g. coppice). Furthermore, any kind of fruit tree can be considered as a woody perennial, but not a forest tree. This is relevant, as permanent crops have no tree density limit to receive Pillar I direct payments during the CAP 2014-2020 period as described in the EU Regulation 1307/2014. However, the use of forest species in permanent grasslands or arable lands limited the direct payments for farmers if above 100 trees per ha, being the maximum number of trees per hectare determined by the Member States, taking into account local pedo-climatic and environmental conditions, and the need to ensure sustainable agricultural use of the land (Hodosi and Szedlak 2018). This threshold and the fact that shrubs/trees should be grazable (animal consumes the woody perennials directly, not the e.g. acorns from the soil) has brought many conflicts but was solved with Omnibus Regulation (2017) and with the adoption of 'established local practices' in some regions.

In the context of rural development, Measure 8.2 'Establishment, regeneration or renovation of agroforestry systems' defines agroforestry as '*land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same parcel of land management unit without the intention to establish a remaining forest stand. The trees may be arranged as single stems, in rows or in groups, while grazing may also take place inside parcels (silvoarable agroforestry, silvopastoralism, grazed or* intercropped orchards) or on the limits between parcels (hedges, tree lines)' (Hodosi and Szedlak 2018).

Agroforestry has been a common land use practice in Europe since early civilization and has traditionally been an important element of European landscapes. However, many of these systems have disappeared due to economic and social changes (a.o. land abandonment, land consolidation and agricultural intensification), and the remaining ones are highly vulnerable (Nerlich et al. 2013). Moreover, since the industrial revolution, agroforestry has often been replaced by intensive monoculture agriculture or forestry. Since the 1990s, agroforestry has been drawing increasing attention as a sustainable land use practice and there have been European initiatives to support and promote its uptake (Smith 2010). Nevertheless, although there are successful examples, the uptake of new agroforestry practices has been limited (Pisanelli et al. 2014; Luske et al. 2016).

According to den Herder et al. (2017) the total area under agroforestry in the EU27 is about 15.4 million ha which is equivalent to about 3.6% of the territorial total area or 8.8% of the agricultural area (UAA), if considering only trees as woody perennials. The greatest extent of agroforestry is occurring in Mediterranean regions. Agroforestry in this area is a complex assemblage of different land covers resulting from the activities of humankind over many millennia (Antrop 2004). Many of the traditional systems are recognised for their high natural and cultural value such as the dehesas in Spain, the montados in Portugal, and wood pastures in Sardinia, Italy. Agroforestry, with varying level of complexity, is also practised in intercropped or grazed olive orchards in Italy and Greece, where olive trees are often mixed with oak, carob, walnut, almond and other fruit trees (Eichhorn et al. 2006). European agroforestry is dominated by silvopasture such as grazed broadleaved woodlands and grasslands with sparse trees like dehesas and montados, but also grazed permanent crops such as olive groves in the Mediterranean and fruit orchards in continental and Atlantic regions (den Herder et al. 2017). Europe, with its significant variability in natural conditions, legislative framework regulating land use and cultural aspects has a huge diversity of traditional and modern agroforestry systems with high environmental and cultural value (FOREST EUROPE 2019). As for an example of contrast to the Mediterranean systems, in the Nordic countries reindeer husbandry has been traditionally practiced in wooden pastures.

1.1 WHY IS AGROFORESTRY SO RELEVANT?

The main drivers of ecosystem services degradation have been agricultural intensification expansion as well as land abandonment (MA 2005). Nevertheless, some multifunctional land-use systems may safeguard ecosystem services (O'Farrell and Anderson 2010; Tscharntke et al. 2005). Agroforestry is one of such land-use systems that provide multiple ecosystem services, combining the provision of agricultural and forestry products with non-commodity outputs, such as climate regulation or aesthetic values (McAdam et al. 2009). Research has recognized the relevant environmental and socio-economic benefits that agroforestry provides. Fagerholm et al. (2016) performed a review of ecosystem services assessment providing the first systematic synthesis of ecosystem services research in relation to European agroforestry, where the following ES services have been identified: (i) provisioning: genetic resources, food, fuel, fiber, (ii) regulating: water regulation, storm protection, erosion control, water purification, fire hazard prevention, biological control, pollination, climate regulation, (iii) cultural: aesthetic values, recreation and ecotourism, cultural heritage values, sense of place, social relations, knowledge systems, and (iv) supporting: provision of habitat and biodiversity, nutrient cycling, soil formation and retention.

Agroforestry has been recognized as a sustainable land management practice that realigns commodity production with safeguarding ecosystem services (Jose 2009). For example, in the Mediterranean, agroforestry practices, e.g. agro-silvo-pastoral systems, may play a key role in preventing or reducing fire risk and intensity in fire-prone forests. Other agroforestry systems, e.g. shelterbelts in agricultural fields, riparian vegetation, short rotation forestry and coppices on abandoned agricultural land, or traditional landscape mosaics, may have positive impacts on landscape resilience, e.g. through increased biodiversity and reduced wind speed and soil erosion, improved water quality and increased carbon sequestration in agricultural land (FOREST EUROPE 2019). Agroforestry can also contribute to reduce the impacts from extreme events such as heat waves or floods acting as an excellent tool to adapt farming systems to climate change, increases shadow for animals and pasture, reduces fertilizer inputs, increases productivity, favours short supply chains, increases carbon sequestration, and enhances landscape heterogeneity (Rois et al. 2019a).

It is a system that increases land resource efficiency and productivity compared to the separated agricultural and forest monocrops (Cannell et al. 1996; Graves et al. 2007). It offers the possibility to diversify agricultural landscapes with trees and to increase overall biodiversity (Mosquera-Losada et al. 2009; Nerlich et al. 2013), This allows increasing the diversification of products and thus the profitability of the system, but also the resilience of the system both to market fluctuations and climate adversities.

Furthermore, this land use system has been recently recognized as a "negative greenhouse gas (GHG) emissions tool" by the IPCC (Global warming of 1.5°C. An IPCC Special Report 1.5 SR ref) at the end of 2018 (Mosquera-Losada et al. 2019a), that may foster sustainability in the current changing climate conditions (Mosquera-Losada et al. 2019b). FAO considers agroforestry nowadays as a sustainable land use and listed as one of the top innovations for adapting agriculture to climate change, encouraging UN Member States to integrate agroforestry in their agricultural policy frameworks to achieve the Sustainable Development Goals.

While large parts of the European farmland suffer from several environmental problems (soil erosion, water pollution from nitrates, low biodiversity, etc.), converting farmland into agroforestry could markedly reduce greenhouse gasses emissions, depending on the type of agroforestry introduced. Kay et al. 2019 estimate that introducing agroforestry systems in vulnerable 8.9% of European agricultural land could potentially store between 1.4 up to 43.4% of the total European agricultural GHG emissions. Furthermore, fires are less likely to occur in agroforestry land in comparison to forest, shrublands or grasslands and when they occur, they are often less intense in agroforestry areas (Rois et al. 2019a; Damianidis et al. 2020).

Nevertheless, agroforestry practices are not yet well-known by many farmers. Given the current global circumstances, where food security is crucial for the increasing global population, climate change is a reality we are facing, and that bioeconomy is one of the solutions, where the economic growth relies within the boundaries of our natural resources, agroforestry is a sustainable alternative to be promoted across Europe.

1.2 POLICY FRAMEWORK

Intensification of agriculture has greatly increased food availability over recent decades. However, this has led to considerable adverse environmental impacts, such as increases in eutrophication of land and water bodies, greenhouse gas (GHG) emissions and biodiversity losses. It is commonly assumed that by 2050, agricultural output will have to further increase by 50% to feed the projected global population of over 9 billion. This challenge is further exacerbated by changing dietary patterns. It is, therefore, crucial to curb the negative environmental impacts of agriculture, while ensuring that the same quantity of food can be delivered. There are many proposals for achieving this goal, such as further increasing efficiency in production and resource use or adopting holistic approaches such as agroecology and organic production or reducing consumption of animal products and food waste (Muller et al. 2017).

Demand for food and other agricultural products is expected to increase significantly, by 50 % between 2012 and 2050. The increasing demand is due to factors such as population growth, urbanization, and per capita increases in income, while the natural resources will become increasingly stressed. Producing more with less while preserving and enhancing the livelihoods of small-scale and family farmers is a key challenge for the future. Substantial improvements in resource efficiency and gains in resource conservation will need to be achieved globally to meet growing and changing food demand, and halt and reverse environmental degradation (FOREST EUROPE 2019).

Climate change is a growing threat to the agriculture sector and its negative effects on agricultural and forestry production are already being felt in many places. Unless climate change is addressed, agricultural productivity will decline with serious implications for food security (Borrelli 2019).

Mosquera-Losada et al. (2017) and Santiago-Freijanes et al. (2021) have identified the main policies addressing agroforestry, resulting in the following selection at global, pan-European and European level (Table 2). Agroforestry can contribute to the implementation of a large number of global initiatives, e.g. the FAO Guidelines for Sustainable Agriculture and Rural Development, as well as European level initiatives including the Pan-European Biodiversity and Landscape Strategy, the European Convention of Landscapes and the European Climate Change Programme. Agroforestry in the EU should be also understood in connection with the Common Agricultural Policy (CAP). In this context, the Cork 2.0 Declaration was established by different policy actors and farmers dealing with agricultural and forestry lands.

Table 2. Main policies addressing agroforestry. Source: Santiago-Freijanes et al. (2021)

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

Along the last years, agroforestry has been taking a more prominent consideration in the European and global policies. Agroforestry is fully aligned with the global 2030 Agenda for Sustainable Development and its Sustainable Development Goals, with the European Bioeconomy Strategy and the European Green Deal. Those are briefly explained below, as well as the relevance of the natural capital in the international arena, and the CAP, which is the target of the current thesis.

1.2.1 Sustainable Development Goals (SDGs)

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, is a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. At its heart are the 17 Sustainable Development Goals (SDGs), also known as the Global Goals, are integrated, i.e. action in one area will affect outcomes in others, and that development must balance social, economic and environmental. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests. Agroforestry Network and Vi-skogen (2018) reviewed and assessed the SDGs where agroforestry has the strongest impact potential. The report presents evidence of how agroforestry can contribute to implementation of nine out of the 17 SDGs, including the economic, environment and social ones. The identified SDGs to which agroforestry can make a significant contribution are poverty reduction (SDG 1) and hunger alleviation (SDG 2), as well as on climate action (SDG 13), and biodiversity conservation and sustainable land management (SDG 15). In addition, the report shows that agroforestry can contribute to other goals by improving gender equality (SDG 5) and health (SDG 3), as well as by increasing access to clean water (SDG 6), sustainable energy solutions (SDG 7), and responsible agricultural production (SDG 12).

1.2.2 Circular Bioeconomy

Economic growth has usually been at the expense of the environment. The need to change our development to a more sustainable economic model, makes bioeconomy to be part of the solution to address some of the most eminent European and global challenges: climate change, biodiversity loss, forest fires, the ocean plastic... The European Commission defines the bioeconomy as "the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy. Its sectors and industries have strong innovation potential due to their use of a wide range of sciences, enabling and industrial technologies, along with local and tacit knowledge." (EC 2012). Furthermore generating less residues across the value chain and recycling those still produced is also key to close the cycle and conform the circular bioeconomy. The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended. Thus the circularity is key in the current Bioeconomy Strategy.

Given that most products derived from fossil fuels can be made from biomass, either woody or other plant species, the opportunities for agroforestry are manifold. Agroforestry is known for the diversification of products that can be obtained in an integrative way in the same land unit, providing a great variety of raw materials that may be transformed into bio-based products. The recently updated Bioeconomy Strategy (EC 2018) proposes three main action areas for leading the way towards a sustainable, circular bioeconomy, among which it is to be highlighted the Action 3: 'understand the ecological boundaries of the bioeconomy', where agroforestry is explicitly mentioned as one of the farming systems that makes an efficient use of ecosystems services and should therefore be promoted. As Kevin O'Connor (Bio-based Industries Joint Undertaking) stated, 'bioeconomy is a challenge and an opportunity for farmers, using better what we use, using well what we don't use yet and use sustainably our natural resources'. Agroforestry can play a crucial role in the bioeconomy development, providing a wide range of bioeconomy products, being old or innovative (Rois et al. 2019b), besides environmental services and the intrinsic resilience of the system. Besides, the circularity of the by-products is one typical feature in these systems. Moreover, the expansion of agroforestry should be based on the use of the woody perennials to compensate their establishment and maintenance costs.

1.2.3 European Green Deal

The European Green Deal was launched at the end of 2019 with the aim at converting Europe in the first climate neutral continent by 2030, making EU´s economy sustainable: no net emissions of GHG, economic growth is decoupled from resource use, and no one is left behind. Its relevance has been empowered/accelerated by the global pandemic on COVID-19 that affected the world in 2020, calling for a green recovery.

Agroforestry is mentioned in the European Green Deal, and in the Farm to Fork Strategy and Biodiversity Strategy, which are part of the European Green Deal. The Farm to Fork Strategy addresses the challenges of sustainable food systems and recognises the inextricable links between healthy people, healthy societies and a healthy planet. The 2030 Biodiversity Strategy stresses the need to safeguard nature for the resilience and wealth of our societies, also reminding us that nature is at the foundation of our food system (Thissen 2020). Furthermore, the Biodiversity Strategy states that ´the uptake of agroforestry support measures under rural development should be increased as it has great potential to provide multiple benefits for biodiversity, people and climate' (EC 2020a).

1.2.4 Natural capital

Although agroforestry contributes to a number of high-level environmental and societal goals, e.g. increased biodiversity and carbon storage, reach food security, combat climate change, improved water quality, and high value agricultural products to name just a few, the value of some of these benefits is not fully perceived by markets and some current policies constrain agroforestry application (FOREST EUROPE 2019). Studies have shown that, although profit provided by agroforestry may vary at the plot and farm levels, at the global level the profit is considerable, especially when environmental services are taken into account. (FOREST EUROPE 2019). Environmental services and natural capital are gaining a momentum in the paradigm change the world is living in. The new Circular Bioeconomy Alliance puts nature at the heart of a global circular bioeconomy, an economic growth that must lie within the planetary boundaries. The Alliance has defined a 10-Point Action Plan to catalyse a Circular Bioeconomy of Wellbeing, which is a call for collective and integrated action to global leaders, investors, companies, scientists, governments, non- governmental and intergovernmental organisations, funding agencies and society at large to put the world on a sustainable path. Action Point 4 'Rethink land, food and health systems holistically' includes agroforestry as one of the practices to restore soil fertility and enabling agriculture to become a net carbon sink, rolling climate change backwards profitably, as it revitalises rural communities and enhances human health (Palahí et al. 2020). In the same line, the Terra Carta, launched early 2021, aims at reuniting people and planet, by giving fundamental rights and value to nature, ensuring a lasting impact and tangible legacy for this generation. Terra Carta offers the basis of a recovery plan to 2030 that puts Nature, People and Planet at the heart of global value creation. In Article 7 'Nature, the True Engine of Our Economy' explicitly includes agroforestry in the actions that the private sector and economic actors could adopt as nature-based solutions that foster species-rich systems over monocultures, or as practices that restore soil fertility (Sustainable Markets 2021).

It is not surprising, that based on all scientific studies that assess how our traditional growth model based on fossil fuels and at expenses of nature, and after different attempts to measure the real growth (e.g. Genuine Index vs GDP, Doughnut Economics…), the UN Statistical Commission has recently adopted a new statistical standard to measure the value of ecosystems. The 'System of Environmental-Economic Accounting– Ecosystem Accounting' (SEEA-EA) provides an accounting framework to measure the contribution of ecosystems to our society, their condition (health) and the services they provide to us, as well as where the services are missing. Ecosystem accounts can also support Sustainable Development Goals (SDG) monitoring, e.g. changes in the extent of forest area, or land degradation and restoration (SDG 15 Life on land), as well as of the European Green Deal (UN 2021). Governments will therefore be able to integrate environment in their growth calculations.

As Palahí (European Forest Institute) states: *'Forests, landscapes and agroforestry can catalyze this vital transformation as they are our main terrestrial natural capital supporting wealth creation in rural and urban areas'* (CIFOR 2021). Agroforestry should therefore attract more policy attention and investment to fulfil its potential (Agroforestry Network and Vi-skogen 2018).

1.2.5 Common Agricultural Policy (CAP)

Among all the EU policies, the Common Agricultural Policy (CAP) has been the most important driver of agricultural management and sustainability in the European Union, thus CAP will be the main policy that this thesis addresses.

The CAP is designed to ensure food production within the sustainable FAO principles. The policy is defined by the European Commission and has to be approved by the EU political bodies (Parliament and Council of Europe). Once approved, the CAP is implemented during a period of 7 years. The CAP is based on two main regulations, commonly called Pillar I and Pillar II, which were developed by Regulations 1307/2013 (EU 2013a) and 1305/2013 (EU 2013b) for the 2014–2020 commitment period. Pillar I is completely funded by the EU and initially linked to land productivity and direct payments, while Pillar II is associated with the environment and rural development and co-funded by the Member States. During the first two years of the 2021-2027 period, the existing 2014-2020 CAP regulations will continue to apply, as set out in the transitional regulation adopted on 23 December 2020. CAP strategic plans are due to be implemented from 1 January 2023. The strategic plans will allow for a greater degree of flexibility between the two pillars and will include the ambitions of the European Green Deal, in particular the Farm to Fork strategy.

The budget of the CAP has been increasing in absolute terms since the first years until 1992 and remained rather stable since then (EP 2021). In contrast, the share of expenditure of the CAP as a share of the EU budget has decreased sharply over the past 25 years, from 74% in 1985 to 37.4% in 2019, and 28,5% for the period 2021-2027, despite the successive EU enlargements, mainly due to CAP reforms and the growing share of other EU policies (EC 2020b).

In the same line of the previous CAP 2007–2013 period, where Pillar I across the EU-27 was worth over three times the budget of Pillar II, for the 2014–2020 period, rural development and environmental issues accounted to near 24% of the total CAP budget. The 2014-2020 CAP budget totalled €408 billion, allocating €291 billion for direct payments (71% of the CAP total) and €17 billion for market measures (CMO) (4% of the total) (Pillar I), and €99 billion for rural development (24%) (Pillar II) (EP 2021).

The EU's Multiannual Financial Framework (MFF) for 2021-27 was adopted on 17 December 2020, where the total allocation for the CAP amounts to €386.6 billion. The first pillar has an allocation of €291.1 billion (€270 billion will be provided for income support schemes, with the remainder dedicated to supporting agricultural markets). For the CAP's second pillar the total allocation amounts to €95.5 billion, including €8.1 billion from the next generation EU recovery instrument to help address the challenges posed by the COVID-19 pandemic (EC 2021).

Receiving support from any of the Pillars is conditional on the fulfilment of certain rules called Cross-Compliance, which refers to minimum requirements on sustainability issues such as water quality and livestock health and welfare. Eligibility fulfilment rules in Pillar I are associated with the use of land for permanent grassland, and arable and permanent crops. The requirements for farmers to receive payments from Pillar II are established by each Member State based on their own interests from a productive and environmental point of view. Pillar II is composed of Regional and National Rural Development Programs that promote the environment but also the livelihood of farmers. One of the aims of this thesis is to analyse and explain the promotion of agroforestry practices within Pillar I and Pillar II of the CAP at the EU level for the period 2014–2020. The forthcoming CAP (2021-2028) aims at providing

Member States with more responsibility on the way that CAP is implemented including eligibility, but makes compulsory to provide results which will be linked to results-based payments (Mosquera-Losada et al. 2019c). CAP Strategic Plans are currently being developed and under approval. One of the most relevant outcomes for the forthcoming CAP is that no tree limit will be established for the European Union for farmers to receive direct payments, that may be established or not by Member States. Moreover, the new CAP systems includes eco-schemes where agroforestry establishment and maintenance together with agroecology and orchards grazing are specifically recognized as an eco-scheme activity by the EU.

1.3 FARMER´S MINDSET

Despite of all agroforestry benefits, it is not currently extensively used. Leading conventional farming systems transition towards agroforestry should be based on farmers adoption. For the policy measures to be effective, it is important to analyse the farmers' experiences and how they understand their activities and context (Boonstra et al. 2011; Bernués et al. 2016) promoting adequate business environment for agroforestry development. Thus, it is needed to know both the barriers and the driving forces for the farmers and/or forest owners to implement agroforestry instead of conventional agriculture and forest management.

The decisions of farmers on whether to implement agroforestry on their farms has been constrained by various socioeconomic and environmental factors (Camilli et al. 2017; Jalón et al. 2017; Rois-Díaz et al. 2018). To promote its uptake, it is important to understand how farmers perceive agroforestry practices and systems and identify what the opportunities and constraints might be from their perspectives.

In the interlinked world we live in, it is relevant to involve various different stakeholders in order to see the complex situation, helping to identify challenges and opportunities, along the whole value-chain. The project AFINET (Agroforestry Innovation Network) created nine regional agroforestry networks (RAINs) in Europe. A multi-actor approach was used to integrate different actors from a bottom-up perspective, including farmers/practitioners, private partners (i.e. SMEs, tree nurseries, private advisors...), multipliers (i.e. sector and professional associations), researchers and policy makers and administration (Villada et al. 2018). The main gaps and bottlenecks identified by stakeholders were grouped under (1) communication and education, (2) technical, (3) economic and (4) policy aspects (Villada et al. 2018; Mosquera-Losada et al. 2019b). Several knowledge gaps in the different aspects, that are linked to the lack of implementation of agroforestry in Europe have been identified as follows (Villada et al. 2018):

> **Communication, dissemination and awareness raising**: farmer awareness of AF benefits (environmental and financial), general public awareness (high quality products and ecosystem services), lack of specialized training including technical, economic and legal aspects, lack of case studies, dissemination, best practice examples, experimental farms.
>
> **Technical management**: information on appropriate species/varieties choice (combination animal/tree/crop), lack of practical guidelines (e.g. pruning, grafting, tree spacing, fertilization, treatments, management), effective and economic seedling/tree protection, lack of pilots and demonstration sites, nutritional value and medicinal function of shrubs, pastures, tree fodder, cooperative use of machinery/animals, animal stocking rate, lack of advisors and admin officers, water

management, droughts and climate change adaptation, lack of specialized human labour.

Economic aspects, chain development and commercialization: better view on the demand, supply and marketing opportunities for AF products (e.g. fruits, nuts, poplar wood, new crops), lack of information on cost/benefit analysis of AF systems as compared to monocrops, finding the right tree/crop/livestock association to improve profitability, lack of valorization of AF products, valorization of the ES AF systems provide, label/certificate/branding for high quality and low impact products, cooperation development for products marketing.

Administrative and legal aspects: lack of inadequate financial or policy measures to support AF, lack of clarity about tree planting under the CAP and its implications, lack of recognition of AF and no legal definition, subsidy system and legislation designed for big companies while average farms are small, incompatible policies.

As for the technical and economic challenges, AFINET and AGFORWARD projects have provided extensive material available, e.g. factsheets, technical reports, videos, a knowledge reservoir. Greater access to research finding and identification of good practices that farmers are already implementing can still be further fostered. There is still a major need for agricultural extension for transfer knowledge to practitioners, but also need for education of the younger generations.

2 OBJECTIVES

Policy formulation must be based on scientific research. In order to be able to influence the policy development and the education and extension activities that would contribute to further implement agroforestry practices across Europe, a diagnose of the current situation is needed.

The present doctoral dissertation aims at discovering the reasons behind European farmers and forest owners to implement agroforestry practices, and analyse how existing policies in Europe affect to the implementation and promotion of such practices.

The main hypothesis of the PhD for agroforestry adoption are:

1. Understanding the challenges that farmers have is key to foster the adoption
2. Expert analysis of the main challenges to enhance agroforestry adoption will develop a better out-farm agroforestry business environment.
3. The understanding and modification of adequate CAP policies will promote sustainable land use, such as agroforestry, in Europe.

The specific objectives of the current research are therefore:

1. Identify the motivations or driving forces and the barriers that farmers and forest owners are facing in order to apply agroforestry practices versus conventional farming or forest management.
2. Analyse with agroforestry experts what are the motivations they consider are relevant to implement agroforestry practices.
3. Analyse how the Common Agricultural Policy (CAP) is influencing the implementation of agroforestry practices in Europe.

The following scientific papers are the results of the research carried out to achieve the above mentioned objectives, respectively:

1. Identification of the driving forces and the barriers perceived by the farmers

Rois-Díaz M, Lovrić N, Lovrić, M, Ferreiro-Domínguez N, Mosquera-Losada MR, den Herder M, Graves A, Palma J, Paulo JA, Pisanelli A, Smith J, Moreno G, García S, Varga A, Pantera A, Mirck J, Burgess PJ (2018) Farmers' reasoning behind the uptake of agroforestry practices: evidence from multiple case-studies across Europe. Agroforestry Systems 92, 811-828. https://doi.org/10.1007/s10457-017-0139-9

2. Perceptions by agroforestry experts on motivations for agroforestry implementation

Lovrić M, **Rois-Díaz M**, den Herder M, Pisanelli A, Lovrić N, Burgess PJ (2018) Driving forces for agroforestry uptake in Mediterranean Europe: application of the analytic network process. Agroforestry Systems 92, 863-876. https://doi.org/10.1007/s10457-018-0202-1

3. Influence of the CAP on agroforestry implementation

Mosquera-Losada MR, Santiago-Freijanes JJ, Pisanelli A, **Rois-Díaz M**, Smith J, den Herder M, Moreno G, Ferreiro-Domínguez N, Malignier N, Lamersdorf N, Balaguer F, Pantera A, Rigueiro-Rodríguez A, Aldrey JA, González-Hernández MP, Fernández-Lorenzo JL, Romero-Franco R, Burgess PJ (2018) Agroforestry in the European common agricultural policy. Agroforestry Systems 92, 1117-1127. https://doi.org/10.1007/s10457-018-0251-5

Other related publications as co-author, not being part of the PhD thesis, are the following:

Santiago Freijanes JJ, Mosquera-Losada MR, **Rois-Díaz M,** Ferreiro-Domínguez N, Pantera A, Aldrey JA, Rigueiro-Rodríguez A (2021) Global and European policies to foster agricultural sustainability: Agroforestry. Agroforestry Systems. Agroforestry Systems 95, 775-790. https://doi.org/10.1007/s10457-018-0215-9.

Santiago-Freijanes S, Pisanelli A, **Rois-Díaz M,** Aldrey-Vázquez JA, Rigueiro-Rodríguez A, Pantera A, Vityi A, Lojkag B, Ferreiro-Domínguez N, Mosquera-Losada MR (2018) Agroforestry development in Europe: Policy issues. Land Use Policy 76, 144-156. https://doi.org/10.1016/j.landusepol.2018.03.014

Mosquera-Losada MR, Santiago-Freijanes JJ, **Rois-Díaz M,** Moreno G, den Herder M, Aldrey-Vázquez JA, Ferreiro-Domínguez N, Pantera A, Pisanelli A, Rigueiro-Rodríguez A (2018) Agroforestry in Europe: a land management policy tool to combat climate change. Land Use Policy 78, 603-613. https://doi.org/10.1016/j.landusepol.2018.06.052

3 METHODOLOGY

In order to reach the above objectives, different mixed methods integrating both technical and social methodologies linked to qualitative and quantitative analyses have been followed to move forward within the state of the strategies and social needs of the agroforestry knowledge. The methodology are specific of three different topics such as the identification of the driving forces and barriers perceived by the farmers to implement agroforestry, the perceptions by agroforestry experts on motivations for agroforestry implementation and the influence of the Common Agricultural Policy (CAP) on agroforestry implementation.

1. Identification of the driving forces and the barriers perceived by the farmers

The methodology selected for the identification of the driving forces and barriers by the European farmers is the Grounded Theory by Glaser and Strauss (1967). It is a qualitative methodology identified as an 'inductive approach for which the data immersion serves as starting point for the theory development of the phenomenon' (Guillemette 2006).

With this purpose, interviews to farmers and forest owners were conducted in several European countries. A minimum of 8 interviews per region were conducted to farmers that implemented conventional agriculture and another minimum of 8 interviews to farmers/forest owners that implemented agroforestry practices, grouped by different sub-systems across Europe. The number of interviews was selected based on when saturation, i.e. answers starting to repeat between farmers, is met. A total of 183 interviews across 8 countries were performed, in particular Spain, Italy, Greece, Portugal, France, Germany, United Kingdom and Hungary.

The qualitative analysis of those interviews is the core task of the first section of this thesis. The interviews addressed the main research question: why is agroforestry implemented or not, and consisted of two types of questions: 'simple', or closed format questions, and 'complex' or open format questions. The latter were used for the qualitative analysis through a thematic narrative, discovering patterns and developing themes. This kind of interpretative analysis attempts to describe, explain and understand the lived experiences of a group of people (Charmaz 1995). Given that the combination of qualitative and quantitative methods is encouraged (Suddaby 2006), in the interview protocol the closed format questions related to the socio-economic situation of the farmers, which were analysed quantitatively. The open responses were analysed qualitatively with the support of the MAXQDA 11.0 software. The software assists in organizing and grouping the above mentioned coding, although the logic is performed by the researcher.

The early coding phase of the analysis consist of marking a time frame with words that describe that period of conversation. Afterwards, the entire interview was coded in such a manner that the codes are systematized by producing 'categories' of codes. Each 'category' contained its explanation, called a 'memo'. This memo contained all the relevant information to describe the code. If applicable, they were systematized further in even more abstract and general groups of codes. This number of codes, memos and categories was kept manageable, to be able to find logic between their connections and find the most important emerging themes. The process of developing the themes divided in A (Conventional agriculture) and AF (Agroforestry) sections consist of the following phases: (i) Stage 1: Developing the code manual, (ii) Stage 2: Finding the connections between the codes, (iii) Stage 3: Summarizing data and identifying initial themes, (iv) Stage 4: Additional coding, (v) Stage 5: Connecting the codes and legitimizing themes, (vi) Stage 6: Summarizing final themes and supporting them with quotations. The coding in several phases allows to create emerging and meaningful patterns.

Each code or concept was constantly compared to all other codes to identify similarities, differences and general patterns. Themes gradually emerge and move from a low level of abstraction to become major themes, until the point they become concepts directly related to the research question, e.g. a category of reasons why is AF implemented or not, or barrier which stops the adoption of AF in a certain region.

The work derived from this analysis resulted in the paper 'Farmers' reasoning behind the uptake of agroforestry practices: evidence from multiple case-studies across Europe'.

2. Perceptions by agroforestry experts on motivations for agroforestry implementation

Modelling based on the Analytic Network Process (ANP) developed by Saaty (1996), a multi-criteria decision analysis, was selected as the methodology to analyse how experts perceive agroforestry implementation. It is based on subsequent questionnaires addressed to agroforestry experts, in an iterative process with several enquiry rounds. ANP is based on pairwise comparisons of its elements. The pairwise comparisons are stated in the form of a question, e.g. 'what is the relative importance/influence of one element ('sender' node) on another element ('receiver' node)?' The answers would be presented in a textual form matching the Saaty's fundamental scale (ranging from 1 for equal importance to 9 for extreme importance).

In this study, the ANP model was developed with separate 'sub-models' for "benefits" (B), "opportunities" (O), "costs" (C) and "risks" (R). Benefits and costs entail criteria that are internal to the decision system and are focused on present, while opportunities and risks entail criteria that are external to the decision system and are focused on future. The decisions were based on a defined description of a situation, what it could be a typical farm in the Mediterranean context, and entailed a limited set of discrete alternative decisions, i.e. farm management alternatives including agroforestry.

A preliminary list of social, environmental and economic criteria that might affect agroforestry implementation was set by agroforestry experts. These results were discussed in a workshop with agroforestry scientists, but also with representation from agroforestry associations and agricultural advisory agencies, where the list of criteria was improved and their relations were drafted. A draft ANP model was designed and sent back to the same group for comments in a form of a questionnaire. The improved model was sent back again to the workshop participants to assign pairwise comparisons between the elements of the model. Respondents also reflected on the importance of individual criteria, their meaning and potential overlap, and on the general structure of the model. The main comment was that the model's complexity needed to be reduced. By eliminating the criteria that were mentioned by the lowest number of respondents, the number of criteria was reduced from 54 to 35. Respondents received a last questionnaire which focused on 'critical' comparisons i.e. comparisons in which opinions of the respondents were divergent. The 'critical' comparison questionnaire comprised 26 out of a total of 73 direct comparisons in the model. Although 22 individuals participated in the first half of the model design, only eight respondents assigned pairwise comparisons between the elements of the model. For this reason, it would be prudent to state that the model was constructed with an input from eight decision makers, which is a minimum number of people that have been involved in a single step of the model design.

After the last questionnaire, there were no more ‘critical’ judgments, and the design of the model was finalized, where the final values of the pairwise comparisons were based on the geometric mean of responses. Only then, the calculation of final priorities and sensitivity analysis was performed. The final model is a full BOCR model with 35 criteria, where the benefits sub-network was further divided into three clusters representing environmental, economic and social benefits. The Benefits sub-network was assigned the highest weight (0.354), Costs and Risks had approximately same the weight (0.239 and 0.221), and Opportunities was given the smallest weighting (0.185).

The results of following this methodology are reflected in the article titled ‘Driving forces for agroforestry uptake in Mediterranean Europe: application of the analytic network process’.

3. Influence of the Common Agricultural Policy (CAP) on agroforestry implementation

The article ‘Agroforestry in the European common agricultural policy’ analyses how the presence and management of woody vegetation was promoted within the European CAP framework (period 2014–2020) extending beyond the agroforestry specific measure in Pillar II, which was included in the CAP in 2007. A review of the different policies and strategies that affect directly or indirectly to the implementation of agroforestry systems was performed, and how these can contribute to the referred goals. In particular, the thesis focuses on the CAP, being the policy with the strongest impact on the agriculture and rural development in Europe. The analysis is based on a literature review of the main CAP legislation framework for Pillar I (Regulation 1307/2013) and Pillar II (Regulation 1305/2013), as well as the accompanying and transposed legislation, such as Delegated Acts and 88 out of the 118 Rural Development Programs existing in the CAP for that period. In particular, agroforestry promotion was evaluated in the sections of the CAP whose fulfilment by farmers is required, such as (i) cross-compliance, whose rules have to be adopted as a prerequisite to get payments linked to Pillar I or Pillar II; (ii) direct payments that include eligibility and Greening measures within the norms required to receive support from Pillar I; and (iii) Pillar II.

Other reports presented by the European Commission in the Civil Dialogue Groups and in the webpage of the European Network for Rural Development were also considered in the evaluation.

The results of following this methodology are reflected in the article entitled ‘Agroforestry in the European common agricultural policy’.

4 RESULTS. CHAPTER 1. FARMERS' REASONING BEHIND THE UPTAKE OF AGROFORESTRY PRACTICES

This chapter is the preprint of the following article: Rois-Díaz M, Lovrić N, Lovrić, M, Ferreiro-Domínguez N, Mosquera-Losada MR, den Herder M, Graves A, Palma J, Paulo JA, Pisanelli A, Smith J, Moreno G, García S, Varga A, Pantera A, Mirck J, Burgess PJ (2018) Farmers' reasoning behind the uptake of agroforestry practices: evidence from multiple case-studies across Europe. Agroforestry Systems 92, 811-828. https://doi.org/10.1007/s10457-017-0139-9

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The contribution of the author of this thesis to this article is the design of the interviews to be carried out with the farmers/forest owners across Europe, literature review, compilation of the English transcriptions of results of the interviews, analysis of the results, and coordination and co-writing of the paper.

4.1 ABSTRACT

Potential benefits and costs of agroforestry practices have been analyzed by experts, but few studies on a European scale have captured farmers' perspectives on why agroforestry might be adopted. This study provides answers to this question, through an analysis of 183 farmer interviews in 14 case study systems in eight European countries. The systems represented included: high natural and cultural value agroforestry systems, silvoarable systems, high value tree systems, and silvopasture systems, as well as systems where no agroforestry practices were occurring.

A mixed method approach combining quantitative and qualitative approaches was taken throughout interviews. Narrative thematic data analysis was performed. Data collection proceeded until no new themes emerged. Within a given case study, i.e. the different systems in different European regions, this sampling was performed both for farmers who practice agroforestry and farmers who did not.

Results point to a great diversity of agroforestry practices, many of the farmers are not aware of the term or concept of agroforestry, despite implementing the practice in their own farms. While only a few farmers mentioned the eligibility as the main reason to remove trees from their land, to avoid the reduction of the funded area, the tradition in the family or the region, learning from others, and increasing the diversification of products play the most important role on adopting or not agroforestry systems.

Keywords: interviews – narrative thematic analysis – driving forces – farming

4.2 INTRODUCTION

Europe is characterized by a predominantly rural landscape (Eurostat 2016). In 2013, there were 10.8 million farms across the EU28, working 174.4 million hectares of land (Utilised Agricultural Area or UAA), i.e. 40% of the total land area of the EU28, while the forested area of the EU is slowly increasing and covers a slightly greater proportion of the land than is used for agriculture, 42% (Eurostat 2016). According to den Herder et al. (2016) the total area under agroforestry in the EU27 is about 15.4 million ha which is equivalent to about 3.6% of the territorial area or 8.8% of the UAA. The same authors sustain that Mediterranean countries such as Spain, France, Italy, Greece and Portugal have the largest absolute extent of agroforestry.

Over the last decades, there has been a clear rural land abandonment and migration of people from rural to urban areas (Renwick et al. 2013; Pointereau 2008; Keenleyside et al. 2010). The motivation for this movement varies between regions but a common factor is related to agriculture profitability (Breustedt and Glauben 2007). The number of farmers in Europe is declining and their average age is going up (EC 2015). Maintaining agricultural activities, particularly in low-productive areas, becomes difficult and agricultural land is abandoned, having consequences beyond the local economy (García-Ruiz and Lana-Renault 2011; Moreira and Russo 2007). To stop abandonment of rural areas, public and private support needs to be enhanced (Olper et al. 2014). Agroforestry is one of the activities that could help to stimulate rural areas by providing additional employment and financial revenue in a sustainable way (Mercer et al. 2014; Valdivia et al. 2009; Rancane et al. 2014).

However, adoption of agroforestry systems has been constrained by various environmental and socio-economic factors. To promote its uptake, it is important to understand how farmers perceive agroforestry systems and identify what the opportunities and constraints might be from their perspectives. However, much research regarding farmers' perceptions of agroforestry has been undertaken in tropical countries, where it has focussed on understanding local practice, opportunities for improvement, and why interventions succeed or fail (Graves et al. 2004; Barrance et al. 2003, Franzel 1999, Fischler and Wortmann 1999; Dreschel and Rech 1998). Much less of such research exists in a European context or in the context of highly mechanised agriculture dominates (Graves et al. 2009). What does exist has examined the use of agroforestry practices within a broad farming systems context, for example as riparian strips (Ducros and Watson 2002), hedgerows (Morris et al. 2002), windbreaks (Matthews et al. 1993), and as silvopasture systems (McAdam, et al. 1997). Such techniques have been accepted by farmers for a number of reasons, for example, because they have an obvious functional benefit (shelter for crops or animals), are existing features of the landscape (hedgerows), or because there may be limited options for the using the land for other activities (riparian strips). In a pan-European survey of farmer perceptions of silvoarable systems in England, the Netherlands, Germany, France, Spain, Italy, and Greece undertaken for the Silvoarable Agroforestry for Europe (2001-2005) project, Graves et al. (2008) reported that 86% of interviewed farmers were willing to use silvoarable systems, but only under particular conditions, the most important of which was confidence in their profitability. In the countries where the survey took place, 16% of farmers did not think there were any benefits at all from silvoarable systems; but 30%, 16%, 11%, and 7% of farmers thought there could be economic, diversification, environmental, and landscape benefits respectively.

Regarding the adoption of new practices, particularly long-term systems, where a new system differs substantially from existing systems, Pannel (1999) has suggested four conditions necessary for adoption: firstly, the farmer must perceive that an alternative system exists, secondly, perceive that it can be trialled, thirdly perceive that it is worth trialling and fourthly perceive that it meets required objectives, particularly profit. These conditions are not easily obtained and in developed countries, three major difficulties inhibit the adoption of new technologies; firstly, developing an alternative system that is more profitable than existing systems, secondly, assessing whether it is more profitable than the current system and thirdly, overcoming the farmer's uncertainty regarding the system.

This study aims to assess which factors act for and against the adoption of agroforestry systems by European farmers, understand the knowledge the farmers have on these systems and identify the reasons why the might have removed trees from their land. The study is framed within the project 'Agroforestry that Will Advance Rural Development (AGFORWARD) that aims at promoting agroforestry practices in Europe that will advance rural development i.e. improved competitiveness, and social and environmental enhancement.

4.3 MATERIAL AND METHODS

Materials

The intention of the interviews was to perform a thematic sampling to address the research question: 'why is agroforestry accepted or not'? An inductive approach was used for exploring a new phenomenon and is usually used in this kind of narrative analysis because it synthesizes data while facilitating broader understanding of data collected.

The selection of the respondents was as random as possible, after the stratification in two groups: farmers practicing conventional agriculture (A), and farmers practicing agroforestry (AF), and under four different categories used in the AGFORWARD project, i.e. (i) High Nature and Cultural Value farms, (ii) high value trees, (iii) silvoarable and (iv) silvopasture. Those farmers not implementing agroforestry were selected having a similar production sector in the same region. Interviews were performed either face-to-face or by telephone, in both situations they were asked for a permission to record it.

A total of 183 interviews were performed in eight European countries: Spain, Italy, Greece, Portugal, France, Germany, UK and Hungary. The final number of interviews performed by subsystem and region is shown in Table 1.

Table 1. Distribution of the sampling for performing the interviews to farmers across Europe. AF: agroforestry, A: conventional agriculture.

Agroforestry system	Partner	Country	Number of AF interviews	Number of A interviews
High Nature and Cultural Value (HNCV)	TEI	Greece (EL)	8	8
	ISA	Portugal (PT)	8	8
	UNEX	Spain (ES)	9	8
	BTU	Germany (DE)	8	8
High value	CRAN	United Kingdom (UK)	5	0
	AFBI	United Kingdom (UK)	1	10

trees (HNV)	USC	Spain (ES)	4	7
Silvoarable (SA)	ORC	United Kingdom (UK)	9	4
	TEI	Greece (EL)	8	8
	BTU	Germany (DE)	8	8
	AFAF	France (FR)	8	9
Silvopasture (SP)	USC	Spain (ES)	9	7
	NYME	Hungary (HU)	7	0
	CNR	Italy (IT)	6	0
			98	85
		TOTAL	183	

Saturation, i.e. answers starting to repeat between farmers, was observed on average with 8 interviews. In the cases where less interviews were performed, the causes varied from difficulty to get the farmers involved, or that was not possible to identify conventional farms in those regions, e.g. sheep were farmed in agroforestry land exclusively in Italy and Hungary.

This research tried to enhance generalizability by doing a thorough job of describing the research context and the assumptions that were central to the research, however the problem remains with the transferability, because the researcher who will in the future try to "transfer" the results to a different context will be responsible for making the judgment of how sensible the transfer is (Fereday and Muir-Cochrane 2006).

Farm characteristics and farmers socio-economic status.

Several practices have been described by the agroforestry farmers interviewed, while it must bear in mind that these are not all existing practices in Europe, but the only ones present in this study. Those are High Nature and Culture Value, hedgerows, grasslands with scattered trees, montado, dehesa and other wooded pastures and grazing in dense forest. In some cases of silvopasture systems, the grazing takes place only for a few months in the year, while in many cases they practice holistic grazing all year round.

A large part of the farmers (86%) are male. Over half of the farmers (62%) consider themselves as farmers or farm managers, 7% livestock breeders, 6% farmers with a second occupation, e.g. researcher, teacher, technical advisor, consultant, business man, forest company, 5% fruit growers and the remaining 20% have other occupations as main source of income, e.g. civil servant, carpenter, consultant, metal worker, shepherd, teacher, veterinary.

Concerning the level of education, half (53%) of the farmers hold university degrees, mainly in the agricultural sciences. A 19% hold a high school degree and another 17% had only elementary studies. A small sample (3%) was educated in a vocational school, while a similar number (3%) did not have any studies. A few farmers were reluctant to share their level of education (5%).

As average, farmers were 48 years old, while the age range was 23-80. The number of descendants varied between none and 7, being 1.5 children the average.

There is a big variation between the farms, from very small (0.1 ha) to very large (11,000ha). The largest farms correspond mainly to the ‘montado’ and ‘dehesa’ systems in Portugal and Spain, thus the standard deviation (STDEV) is rather high. There is also difference in the subsidies claim, from farmers that do not apply for any subsidy to those that get subsidies for the whole farm area (Table 2). The parameter 'CAP 2007-2013 vs total size' refers to the comparison to the actual size of the farm, thus we can observe that most of the farmers claim the entire farm under the CAP (MODE = 0), while the average says that not all the hectares are claimed (MEAN = -128.34). As for the parameter 'CAP 2014-2020 vs CAP 2007-2013', most of the farmers claimed or are planning to claim the similar area (MODE = 0), while the trend is to increase slightly the area under subsidies (MEAN = 3.47).

Table 2. Size of the farms of the interviewed farmers and area eligible claimed under the CAP 2007-2013 and CAP 2014-2020. MEAN is the average, MIN is the minimum value, MAX is the maximum value, STDEV shows the dispersion of a set of data values, MODE shows the most frequently occurring value in the range of the data.

Area (ha)	MIN	MEAN	MAX	STDEV	MODE
Size of the farm	0.1	363.10	11,000	993.84	20
Size eligible CAP 2007-2013	0	242.24	6,612	674.30	0
Size eligible CAP 2014-2020	0	263.34	6,612	697.14	0
CAP 2007-2013 vs total size	-4,388	-128.34	0	448.26	0
CAP 2014-2020 vs CAP 2007-2013	-70	3.47	320	33.39	0

Methods

A series of qualitative interviews were made to farmers that implemented and not implemented agroforestry, grouped by different subsystems across Europe, were analyzed following the inductive research methodology of thematic analysis. Thematic narrative analysis is a categorizing strategy for qualitative data, by doing data review, making notes and sorting it into categories, adapted from Cresswell (2009). As a data analytic strategy, it helped moving the analysis from a broad reading of the data towards discovering patterns and developing themes (Cresswell 2009; Merriam 2009). The intention of the qualitative interviews carried out across Europe was to address the question, 'why is agroforestry accepted or not?'.

There were two types of questions in the interviews: 'simple', or closed format questions, and 'complex' or open format questions. The 'complex' questions were the ones through which the thematic narrative was sought, and was appropriate enough for qualitative analysis.

Inductive approach on thematic narrative analysis was used for exploring the agroforestry application phenomenon, adapted from Saldana (2009). Thematic narrative analysis is useful because it synthesizes data while recognizing the contributions and facilitating broader understanding of data collected (Fereday and Muir-Cochrane 2006). Thematic analysis is one of the most common form of analysis in qualitative research. It emphasizes pinpointing, examining, and recording patterns (or "themes") within data (Guest 2012). Themes were seen as patterns across the data sets that were important to describe the agroforestry application phenomenon and were associated to our research question. The themes become the categories that derived from the analysis. Thematic analysis was performed through the process of coding in several phases to create emerging and meaningful patterns. The process of developing the themes divided in A and AF sections is the following: (i) Stage 1: Developing the code manual, (ii) Stage 2: Finding the connections between the codes, (iii) Stage 3: Summarizing data and identifying initial themes, (iv) Stage 4: Additional coding, (v) Stage 5: Connecting the codes and legitimizing themes, (vi) Stage 6: Summarizing final themes and supporting them with quotations.

This kind of interpretative analyses attempts to describe, explain and understand the lived experiences of a group of people (Charmaz 1995). The raw data in the beginning of the analysis were given conceptual labels. Each code or concept was constantly compared to all other codes to identify similarities, differences and general patterns. Themes gradually emerge and move from a low level of abstraction to become major themes, until the point they become concepts directly related to the research question (e.g. a category of reasons why is AF implemented or not, or hurdle rate which stops the adaptation of AF in a certain region). The analysis starts by the researcher listening the recording, and marking a time frame with words that describe that period of conversation. Several elements were used simultaneously to describe a segment of the interview. This was the initial coding phase. After the entire interview was coded in such manner the researcher tried to systematize the codes by producing 'categories' of codes. Each 'category' contained its explanation, called a ‘memo’. This memo contained all the relevant information to describe the code. If applicable, then the researcher tried to systematize them further in even more abstract and general groups of codes. The groups of codes found did not necessarily relate to the questions within the interview protocol. They were also related to any possible themes that bring about some understanding of the research question (i.e. why is AF accepted or not). Some of them had multiple levels of codes. This number of codes, memos and categories was kept manageable, so the researcher can still be able to find logic between their connections and find the most important emerging themes.

Three types of coding were performed on the data: ‘initial’, ‘in-vivo’ and ‘pattern’ coding:

I. ‘Initial coding’ refers only to condensing the data to more manageable (shorter) units that can be listed and categorized more easily in the later phases. The essence of the ideas was captured with a few words, and the transcribed text was condensed. This is quite purely inductive thematic research, meaning there were no hypotheses to test, but just iterate the data towards new finding. In other words, as a rule there were no predefined categories.

II. ‘In-vivo coding’ or direct quotations for either particularly typical or unique aspects (definitions, causalities, etc.) were written down for each question. This was done during the other coding rounds.

II. ‘Pattern coding’ is an iterative process of categorizing the initial codes (i.e. the shortened text fragments) into relevant meta codes and sub-codes. It identifies patterns from the condensed data, leading to a system of sub-codes to develop a set of main themes and related sub-themes, in which the researcher inserts the finding into it. Judgement by the researchers who analysed the data was applied and additional categorizations were performed where needed. Some of them were overlapping but, in all the cases, they were categorized as meta-codes in general themes and sub-codes in sub-headlines. Categorization of the variables was performed in the end. Some of the ‘answers’ to this question were found under some other topics that are not covered by the interview protocol as they were asked in questions in the subsequent interviews. The definitions of codes and of their memos evolved as they progressed through the analysis.

Relevant ‘in-vivo quotations’ are shown between quotation marks and in italic font, followed by the country and partner recording it. When elaborating the emerging themes on the questions, the acronyms used in Table 1 are used, i.e. country, partner, type of farming practice (A/AF) and type of system.

Given that qualitative and quantitative methods are encouraged to be combined (Suddaby 2006), in the interview protocol, there was also a socio-economic overview, which was analyzed quantitatively. Though the sample and qualitative analysis of the answers has no statistical significance to draw general conclusions, it was used to support the findings in from the interviews. The open responses were analyzed qualitatively with the support of the MAXQDA 11.0 software (MAXQDA 2016).

4.4 RESULTS

Farmers' concept of agroforestry

When trying to find an answer to our research question ´why agroforestry is implemented or not' we looked at different concepts and features or properties that are linked to the driving forces behind the farmers. Before finding the reasons, there was a need to interpret what was understood by the term 'agroforestry'. The most common definition by the farmers across Europe, for both agroforestry and non-agroforestry farmers, was that it is 'a combination of trees and other crops or animals'. This definition was generally accepted without providing major details, though it is recognized that variations exist between their definitions, e.g 'trees integrated with arable land or livestock', 'trees in the fields', 'forest and agricultural productions in the same land', 'combination of forests and livestock'. Nevertheless, some farmers have shown a more comprehensive knowledge of what agroforestry is, giving more details on the concepts, e.g. including woody vegetation as one of the components, not only trees but also shrubs, in combination with agriculture (grasslands/pastures) and livestock (e.g. dehesa), with the remark to obtaining revenues from different sources or products (cattle, sheep, goat milk and meat, fruit trees, timber, biomass, crops...), coming at least one product from the understory.

> 'In society, agroforestry is a new word for something extremely old and large. For example, hedgerows in this country, but there are systems even older than that. They have seen evidence of stone age hill systems in Devon, UK which resemble alley cropping - Devon hedges 12m apart going up a hill side. People do not recognize the extent of agroforestry at the moment e.g. reindeer farming on 10's of million ha.' (UK_ORC_AF_SP)

Results also showed that the concept of agroforestry was not clear for many conventional farmers that do not practice agroforestry. Some farmers defined it like growing trees, others related the definition with the promotion of trees in agriculture, while others thought that it is about integrating woodlands with crops (i.e. apple rows in crops), planted forest with arable field like corn or wheat, or grazed forest. Other farmers referred only to particular practices that were familiar for them: trees planted in strips, plantation for biofuels, or as short rotation coppice. Actually, agroforestry was a concept that was never heard in many cases, especially by conventional farmers. What was more striking, was that there is a lack of awareness among the agroforestry farmers, as many of the them were not aware of the term or concept of agroforestry, despite implementing the practice in their own farms. This confirms the need to implement communication and education forward farmers, advisors, policy makers concerning agroforestry issues.

Driving forces of adoption

The interviews aimed at identifying whether there were divergent or convergent reasons for both conventional and agroforestry farmers to have decided on their farming approach.

The three main drivers observed for implementing conventional farming were the tradition, the lack of knowledge on agroforestry and an easier management. Tradition was the main reason to continue the farming as it was inherited or that was common in the region. It was what they knew that it works, as they were exposed to that practice. They might have chosen more sustainable agricultural practices, i.e. organic farming, but they lacked knowledge on what agroforestry is, how to implement it, the technical design, and its economic viability. In relation to the lack of knowledge, most of the farmers did not consider agroforestry as an economically viable option, requiring also a higher investment for the establishment and maintenance. Furthermore, they did not see any added value from the agroforestry products, considering that there was no demand in the market for agroforestry products and that the crop production would be reduced if trees are present.

Farmers used to choose practices that receive subsidies, although they were not aware of the subsidies for agroforestry, which, in any case, are rather limited. Nevertheless, European Commission recently recognized the social and environmental value of agroforestry systems (EU Reg. 1698/2005) and specific measure supporting agroforestry was introduced in the 2007-2013 CAP. The measure was then improved in the 2014-2020 programming period (EU Reg. 1305/2013) and it is expected that its uptake would increase in the next few years.

Conventional agriculture was also considered easier to manage, and better known. Farmers perceived that management issues are the main constraints to limit agroforestry adoption. Some of the farmers also considered that having animals makes it more complicated for having to find feed for the animals during winter, trees complicate the mechanization and sometimes trees are not compatible with grazing. For instance, in grazed apple orchards animals had to be taken out of the system during several months because of herbicides spraying. Thus providing an area for the animals during these months can be difficult for many farmers.

> 'Mechanization was the main reason not to put trees.' (FR_AFAF_A_SA)

Presence of trees on arable lands obstacles the mechanization and for this reason trees were removed from rural landscape since the industrial agriculture was adopted in more intensive agricultural areas. Some farmers considered that agroforestry needs more time dedication, that there is more work to be done and they lack the time and human resources to work on the farm confirming that agroforestry systems are complex systems that require specific technical skills. If the plots are small, farmers did not consider other farming options as profitable, at least with the current CAP payment scheme. On the other hand, high quality soil is a scarce resource to be maximized, thus many farmers having a very productive soil preferred to maximize its production and use it only for agriculture. They considered trees occupy a very valuable land, an expensive resource, thus agroforestry becomes for them an opportunity cost.

> 'Land is a very valuable scarce resource, for which the production must be maximized, especially if it is a high-quality soil, or if the plots are small.' (DE_BTU_A_HNVC)

Another driving factor influencing the type of farming was the age. Farmers that were close to retire were not interested in new types of farming and would keep doing what they have done their whole life. Young farmers are more interested in introducing innovative practices (García de Jalón et al. 2013). Ownership of the land was also be limitation, as farmers that are renting the land cannot introduce trees as the owners do not usually want to plant any trees. Past research has shown that land ownership is frequently a barrier to adoption of innovative practices (e.g. Knowler and Bradshaw 2007; García de Jalón et al. 2015).

Interestingly, many farmers were interested in the agroforestry practices introduced by the interviewers and considered to give it a try after the interviews, but would need to see examples that those practices are profitable to decide to invest on those, and see other advantages. In order to attract farmer interest in investing lands with agroforestry systems, it should be relevant to create local demonstration plots where agroforestry practices are tested. Some would implement those if there would be economic supporting measures, they perceived that the management was simple and if there were no difficulties with the landowner.

Moving into the agroforestry farmers' vision, many different reasons were identified by the different farmers to decide implementing agroforestry, while the three main drivers were the tradition, the diversification of the products and learning from others. Again, the tradition in the family or in the region, similarly to conventional farmers, influences the decision of most of the farmers to continue with the existing agroforestry system since old times. Behind that, there are cultural reasons and the acknowledgment of the benefit of the synergies between the different components. Agroforestry provides a diversification of products (wood, fodder, meat, milk, crops), which contributes to increase the production and the profitability of the farm with several lines of income, maximizing revenues and reduces some costs e.g. associated to land clearing. Agroforestry allows to have fodder for the animals in winter time and pastureland instead of not useful dense shrubs. Furthermore, products obtained in agroforestry were always identified as high quality products. The diversification of products and synergies among the components (trees, animals and crops) decreases the risks in crop production due to weather events or market changes.

> 'Pastures without trees are more vulnerable to weather conditions.' (PT_ISA_AF_HNCV)

Learning from others and seeing the benefits was an encouraging driver to implement agroforestry practices. Sources of learning were varied: attending a meeting, working abroad, colleagues or other farmer experiences, internet, etc. Also research purposes led to new agroforestry farms, as farmers were contacted for research purposes and used their farms as a demonstration plot. For these reasons it should be promising to establish and/or reinforce networks among stakeholders in order to facilitate the flow of knowledge. Innovative farmers can find empirical solutions to their problems and experiment themselves agroforestry practices.

Not productive soils do not provide relevant crop production, and small fields in difficult areas are hard to manage, thus agroforestry became an alternative in marginal lands, which at the same time improves the soil condition (fertility) and increases the biomass production. Under this point of view, in many marginal areas agroforestry systems are relevant to keep human presence in most remote areas by providing a low but sustainable source of income.

> 'The silvopastoral system was introduced because arable crops are not convenient (poor production) in marginal lands.' (IT_CNR_AF_SP)

In many marginal areas intensive agriculture was not possible to be implemented due to limiting factors (poor soils, slope morphology) and in these conditions agroforestry can be the valuable alternative. Thus, agroforestry offers a sustainable alternative that can lead to a reduction in rural land abandonment.

Agroforestry improved the environment around the farm, hedgerows protect from wind and water erosion, animals decrease the risk of forest fires (with associated cost reduction for land clearing), provides shelter for animals and birds, is good for the environment and nature conservation in general, including a solution for the pollination of trees.

> 'I started to combine apple trees with bees to increase pollination because the trees had pollination problems.' (ES_USC_AF_HNV)

Agroforestry had a high aesthetics value for the farmers, thanks to their different components, it was considered as a nice landscape and as part of the cultural heritage. Some agroforestry systems may result, thus, in more tourism in rural areas and more rural employment, thus motivating farmers. Some aware farmers defended animal welfare (less stress, better quality feed) as a priority, e.g. poultry grow in their natural environment and lambs receive shelter in their first days. For instance, silvopastoral systems increase animal welfare, especially in Mediterranean hot summer trees provide shadow to animals.

Agroforestry was considered as a complex system that provides a more efficient management of the resources and increases sustainable eco-intensification. A sustainable production was given priority over conventional agriculture when it was a second occupation, and not the primary source of income, given that it might not be as productive as conventional farming, chosen when there is a pressure to make profit. Agroforestry perfectly match the need to promote multifunctional agriculture as stated by the main international agreements and institutions.

Subsidies were also an incentive to apply agroforestry, to ensure the farms were profitable. Furthermore, different laws and regulations, like e.g. on hedgerows in Germany might impose restrictions on applying other practices rather than the existing ones.

> 'The system is historical. The hedgerows were already established 300 years ago and are protected by the law. It is not allowed that they are removed. I am an agricultural farmer and if I could I would remove them.' (DE_BTU_AF_HNCV)

Tables 3 and 4 reflect all the driving factors identified above for the different regions in Europe.

Table 3. Drivers for the farmers practicing conventional farming. The symbol '●' in the cell indicates which driver was identified by the farmers in the different countries.

Driving factor	France	Spain	Germany	Portugal	Hungary	Greece	UK	Italy
Tradition	●	●	●				●	
Lack of knowledge on AF		●	●	●		●	●	
Profitability		●	●	●		●	●	
Not aware of subsidies for agroforestry						●		
Easier management	●			●		●	●	
Less time dedication		●				●		
Small plots		●	●			●	●	
Scarce high quality soil			●	●				
Age		●						
Rented land			●					
Willingness to try AF	●	●	●	●		●		

Table 4. Drivers for the farmers practicing agroforestry. The symbol '●' in the cell indicates which driver was identified by the farmers in the different countries.

Driving factor	France	Spain	Germany	Portugal	Hungary	Greece	UK	Italy
Tradition		●	●	●	●	●		●
Diversification of products		●	●	●	●		●	
Learning from others		●	●				●	
Marginal lands	●		●					●
Improving environment		●	●	●	●			
Landscape coherence	●		●					
Aesthetics value for tourism			●	●	●		●	
Animal welfare		●			●		●	
Use existing fences							●	
Quality of life		●						
Research purposes			●				●	
Sustainable eco-intensification				●			●	
Second occupation			●					
Subsidies		●					●	
Regulations			●					

Removal of trees from the landscape

Agroforestry farmers did not see any problem having trees on the grasslands, but the first reason for removing trees and shrubs was to facilitate management to install and maintain their grasslands and having wood pasture instead of having a dense shrub land. Some obstacles that trees may generate are the difficulty using the tractors or machines for the installation and/or the maintenance of the pastures due to the distance between trees, or the damage that tree regeneration suffers due to the presence of the animals. Some farmers have removed a few fruit trees growing on the farm boundaries because they were an impediment for farm machinery. At the same time, some farmers considered the trees as a focus of diseases, and attracting birds that eat the seeds.

> 'In order to protect cork oak roots I am not able to use disc harrow and instead have to use mounted knifes or chains. This last equipment is more restricted when wanting to renew the pastures.' (PT_ISA_AF_HNCV)

Trees have been also removed from the fields as part of tradition, or to establish a new more profitable crop, e.g. olive trees. Only a few farmers mentioned the eligibility for the CAP subsidies as the main reason to remove trees from their land, to avoid the reduction of the funded area. In the new CAP (2014-2020) a tree density up to 100 trees/ha is allowed and funded area is not reduced, as the CAP recognizes the role of hedgerows and isolated trees in arable lands.

Regulations may further limit the removal of trees. In some cases, it was not allowed to remove trees in the state owned forests, the forest service did not allow any intervention, and rarely permitted any tree removal, as it was the case in Greece. The hedgerows could not be removed either in Germany.

> ‘We would gladly remove some trees growing in our grasslands which they inherent our flocks and reduce the available grazing land but we are not allowed to by the forest service.’ (EL_TEI_AF_HNCV)

In any case, in most of the interviews, both agroforestry and non-agroforestry farmers, reported that had not removed any trees from their farms on a voluntary basis.

Key barriers restricting agroforestry

When interviewing the agroforestry farmers, three major problems on the implementation of agroforestry were highlighted: problems with farm management, regulation problems and lack of knowledge, among others. Many farmers saw some difficulties in the management, as agroforestry is more difficult compared to conventional agriculture, but did not consider those as barriers. The main problem was that it was hard work to start an agroforestry farm and/or renew an abandoned area. It usually needs high economic resources and it is time demanding. Management costs of the animals are higher, difficult to find a good shepherd, bureaucracy becomes a burden (land and animal registrations, land delimitation and so on), fencing from wild animals, decay of cork oaks, natural regeneration, although solutions can be found through tree protectors and using other machinery e.g. mounted knifes or chains instead of disc harrow, reducing the number of cows, higher investments for improved pastures, problems with the quality of the pastures where the cows feed as climate fluctuation makes it difficult to provide food only with pastures and frequently they have to buy additional food in the summer to feed the cows, hard to count and look after the animals in the orchards.

> ‘I cannot invest or do anything different from what I do right now due to lack of help. People come and work only for some days and then leave.’ (EL_TEI_A_HNCV)

Wildlife animals (wolves, wild boars) represented another relevant management problem, which was connected to the abandonment of agricultural lands. Lately many lambs were killed, for instance in Italy. Sheep suffered stress and thus the production was limited. Due to the frequent attacks, sheep were recovered to the barn during the night, but was not enough to prevent damages from wild fauna. On the contrary, when the wild fauna was not a problem, sheep were left in the open field for all the time. A preventive selection and monitoring of wolves presence should be carried out by local public institutions.

Some farmers complained on the administrative burden and slow answering from the administration to allow the system establishment and on the CAP limitations and complexity. Moreover, consultants and farmer advisors were not aware of agroforestry limiting the application to RDP measure promoting agroforestry systems.

It was also mentioned as a problem the low profitability and the product price fluctuations, low demand due to the crisis, together with the high costs of establishment (fencing, protectors), changing to breeds more compatible with the trees, the long term for returns (i.e. 15 years from apple trees for a good fruit production). Many farmers perceived a need to create a label for agroforestry products.

In any case, it was positive that many of the remaining farmers did not identify any problem while managing their agroforestry farms.

4.5 DISCUSSION

There are not many studies apart from Graves et al. (2009) on the driving forces behind farmer's behavior at European level, but there are some studies on particular regions or socio-economic environments (Sereke et al. 2016).

There are several threats to the validity of the results in this study due to wide variety of interpretations from multiple researchers doing the analysis. In addition, with thematic analysis nuanced data could be easily missed. Furthermore, the flexibility of analysis makes it difficult to concentrate on what aspect of the data to focus on and the discovery and verification of themes and codes mixed. Finally yet importantly, there is the limited interpretive power and generalizability if analysis excludes theoretical framework (Gregg 2012), there is a small degree to which the results of this qualitative research can be generalized or transferred to other contexts or settings.

Domínguez and Shannon (2011) state that land owners manage their lands having in mind four axis: economic expectations on the property, ethical reasons, how the land should look like, and the natural risks. The relationship between socio-psychological factors (e.g., cultural, demographic, economic, and social variables, including ancestors, peers and education) and how people make decisions in practicing agroforestry is inseparable, and must be considered if policy makers, extension agents, and agricultural educators hope to influence and improve landowners' agroforestry management (Saha et al. 2011).

Based on the responses of the conventional farmers in this study, three major drivers for implementing conventional farming instead of agroforestry were tradition, the lack of knowledge on agroforestry and a simple management. Nevertheless, other factors affecting the decision were the economic viability, existence of subsidies, time needed for dedication, high quality soil, as well as the age of the farmer and the ownership of the land. One of the reasons for not establishing agroforestry was that when planting trees, the land would be tied up for future uses. This finding appeared as the most important factor in the study performed by Flexen et al. (2014) in Ireland, showing that farmers, both agroforesters and non-agroforesters, would consider planting trees in their plots, if there were greater financial incentives, or if they had land that was poor or unsuitable for farming (Flexen et al. 2014). A common attitude found amongst many farmers, both in our study and the previously mentioned, was that farmers did not seem to plant trees in rich soils because of a lower farm net margin. They stated that they would only plant trees on marginal land where farming was difficult or not profitable. Several studies examined the attitudes of UK farmers to planting farm woodlands. In general, these studies showed that most farmers viewed forestry as an inappropriate use of productive land and irrelevant as an alternative source of income, primarily because planting incentives for conventional forestry were seen as inadequate to remove land from farm production. Doyle and Thomas (2000) suggest that as agroforestry involves the diversification of existing agricultural systems, and maintains the majority of the land area in agricultural production, it should encounter less resistance from farmers. They note that a key limitation is a lack of awareness of agroforestry among farmers.

To motivate farmers to manage more complex agroecosystems that are fundamentally different to their current simplified systems is challenging (Pannell 1999). Interestingly, many farmers interviewed in this study showed interest in the agroforestry practices and considered to implement it in their farms. This reflects the openness and willingness but the lack of knowledge the farmers have on other farming options, and would need to see examples that those practices are profitable and have many other advantages to decide to invest on them.

The results in this study are in line with Saha et al. (2011) that indicate that farmers' decision-making processes were most influenced by factors such as ancestors and education, followed by peers, financial condition, and economic importance of the agroforestry land holding. Nature conservation managers, who are actually the farmers of the protected areas, attitude to implement agroforestry management based on traditional ecological knowledge was determined by ancestors and childhood memories, mainly by their own experiences and not their studies (Varga et al. 2016).

When looking at the agroforestry farmers' drivers, also the tradition and learning from other experiences appeared as main reasons for implementing agroforestry, together with the diversification of products, which reduces the risk in the production, another relevant aspect for the farmers. These main drivers contrast with those of farmers in other European regions not included in this study, e.g. Switzerland, where the primary motivations were habitat function, both for biodiversity conservation and shade for livestock (Sereke et al. 2016). Nevertheless, animal welfare was also mentioned as important driver among the interviewed farmers. Animal health and biodiversity played a role in the motivations of farmers in Estonia too (Roellig et al. 2015). Most farmers believed their animals thrive better in a more "natural" environment, needing less medication. In a similar study in Ireland, most of the agroforesty farmers rated landscape improvement and environmental factors as very important factors, as well as provision of shelter for livestock.

The farmers in the current study considered agroforestry as a good alternative for not very productive marginal lands. Improving the environment, aesthetic value and quality of life were further reasons for implementing agroforestry. Similarly, the motivation to conserve cultural landscapes through agroforestry was lower among non-adopters in Switzerland compared to adopters (Sereke et al. 2015). Other studies in France revealed that the difficulties in accessing the land and the need to reduce agricultural inputs through functional biodiversity and diversification motivated smaller farmers to combine annual plants and fruits with the aim to increase their plot performance on a multifunctional basis, increasing the number of such plots significantly in the last years (EURAF 2015).

Existing subsidies also encouraged farmers to manage the land in certain ways. Furthermore, other studies have shown that the availability of grants did appear to influence those who are already interested in planting trees on the fields but not those that who are not (Lawrence et al. 2010). Roellig et al. (2015) identified in Estonia that the determinant factor to manage or restore the wood-pasture was the financial support. On the other hand, most farmers had a clear passion for managing their land and were proud of maintaining their wood-pastures following local traditions.

Regulations, on the contrary, might affect limiting the use of the different agroforestry structures (e.g. hedges) and lands. These reasons were observed also in Switzerland with policies shifting from promoting trees or not in the farms (Sereke et al. 2016). The perceived behavior revealed that farmers felt rather free to decide whether to practice agroforestry or not, but they believed that framework conditions rather do not allow adoption. Environmental regulation was not a motivation, then, for both adopters and non-adopters.

Thus, although factors as stewardship, or farmer image might motivate a small number of farmers to use agroforestry systems, on a wider scale, voluntary adoption of agroforestry systems may need to be encouraged through subsidies, tax relief, or cross compliance, and compulsory adoption through government strategic plans, or penalties for non-adoption (Pannel 1999). Sereke et al. (2016) also justify subsidies for ecological production, and incentivize the local and autochthonous agricultural products. Public support to land management is justified when such management provides public goods, e.g. environmental or social benefits as rural vitality (EBCD 2012).

In order to encourage farmers to take up agroforestry, there is a clear need for raising awareness among the farmers about the benefits of these practices, showing them examples of successful farms. Limited awareness of agroforestry among farmers and landowners was identified in the current study and by a number of studies (McAdam et al. 1997; Doyle and Thomas 2000). For example, in a study by Graves et al. (2009), only 33% of farmers correctly defined agroforestry as the integration of trees with crops or livestock systems. These studies showed, however, that where farmers were shown agroforestry systems, their level of interest increased. Farmer-led projects have greater credibility in the eyes of other farmers (the peer-to-peer effect), thus one channel for such awareness raising is to update the extension services with latest developments and findings for further knowledge transfer. It was actually proved by Primmer and Karppinen (2010) that the technical solutions suggested by the technicians from extension services are well taken by the owners into their decision-making. Technicians are a relevant influencing agent for the owner to decide on the different management alternatives, in particular in cases with high uncertainty and complexity, e.g. price fluctuations and climate change (Schläuter and Koch 2009). Hauck et al. (2016) indicate that at the local level, technical journals were an important source of information for farmers, advising them, for example, on the different agri-environmental schemes that were available, while the linkages between farmers and all stakeholders for exchanging information are encouraged.

There is also a clear need for awareness raising among the consumers, for them to give priority to agroforestry derived products despite of a higher price, which in turn becomes an incentive for farmers. Duesberg et al. (2014) also recommended that, in addition to monetary incentives, policy tools such as image and information campaigns should be used. A broader knowledge about ecosystem services needs to be made available to farmers and to the society at large, to increase recognition of local ecological solutions (Sereke et al. 2016).

4.6 CONCLUSIONS

The main driver for the farmers, both conventional and agroforestry, to apply conventional or agroforestry farming, was the tradition in the family or the region and continue with the existing system since old times. Besides, the knowledge on existing successful practices was an encouraging driver for the uptake of agroforestry practices. Interestingly, there was a lack of awareness on agroforestry, as many of the farmers were not aware of the term or concept of agroforestry, despite implementing the practice in their own farms. Furthermore, the lack of knowledge lead to misconceptions or wrong assumptions, as it was observed in the perceptions the farmers have on agroforestry practices. Many farmers would be willing to implement agroforestry if they would have available more knowledge on those, their profitability, benefits and practical know-how.

Hesitating farmers would like to apply or expand agroforestry in their farm if the systems would be rewarding from an economic point of view. Only a few farmers considered the eligibility of their land to the existing subsidies as the main reason to remove trees from their land, to avoid the reduction of the funded area. Subsidies within the CAP should favour this type of farming with more measures, which should also be explained thoroughly and encouraged by the extension services, increasing the awareness of grants available besides the practical knowledge on the management and alternatives. Raising awareness of the consumers on the quality of the agroforestry products and the ecosystem services provided by the agroforestry systems is also essential for encouraging farmers to practice agroforestry.

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5 RESULTS. CHAPTER 2. DRIVING FORCES OF AGROFORESTRY AT THE GROUND LEVEL. APPLICATION OF AN ANALYTIC NETWORK PROCESS

This chapter is the preprint of the following article: Lovrić M, Rois-Díaz M, den Herder M, Pisanelli A, Lovrić N, Burgess PJ (2018) Driving forces for agroforestry uptake in Mediterranean Europe: application of the analytic network process. Agroforestry Systems 92, 863-876. https://doi.org/10.1007/s10457-018-0202-1

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The contribution of the author of this thesis to this article is the co-creation along the process and iterations of the questionnaires to be answered in by the agroforestry experts, literature review, compilation of the results of the questionnaires and co-writing of the paper.

5.1 Abstract

The Mediterranean area, due to the favourable climatic conditions, is particularly suitable to host agroforestry systems in the rural landscape. Sunlight, as one of the major drivers for plant growth, is often in excess and hence a strong reason for shade demand by trees though agroforestry systems. Additionally, seasonal water shortage or even severe summer droughts are not rare in the Mediterranean area. Portugal, Spain, Italy and Greece have the largest absolute extent of agroforestry in Europe.

In order to shed light on the factors that frame the implementation of agroforestry practices in Europe, an Analytic Network Process model has been designed to reflect farm management scenarios for the Mediterranean biogeographical region in Europe, in which a ‘typical’ farm could improve its management system by implementing different agroforestry practices. This corresponds to five management alternatives: Implement High Natural and Cultural Value agroforestry system, Implement High value tree systems, Implement Agroforestry for arable systems, Implement Agroforestry for livestock systems and Do not implement agroforestry system. The model was developed in a participatory manner through series of questionnaires and workshops.

In general, all the Mediterranean agroforestry systems were associated with high benefits and opportunities, but also with high costs and high risks. The greatest benefits however, were attributed to High natural and cultural value agroforestry systems, which greatly contributed to the highest priority of this system. Overall results show robustness in the sensitivity analysis with one exception – when the importance of costs is high, no agroforestry becomes the alternative with highest priority.

Keywords: Multiple criteria decision analysis (MCDA), Analytic network process (ANP), Mediterranean, drivers

5.2 INTRODUCTION

Agroforestry was a common land use practice in Europe since early civilization. However, since the start of the industrial revolution this practice gradually started to be replaced by more intensive mono-crop agriculture and forestry. Over the last decades, agroforestry as a sustainable land use practice has been drawing increasing attention again and there have been some initiatives to support and promote agroforestry (Smith 2010). Nevertheless, despite these initiatives, the uptake of new agroforestry practices has remained quite limited (Pisanelli et al. 2014; Luske et al. 2016), although there are some successful examples across Europe. The decision of a farmer for whether or not to practice agroforestry on his or her farm depends on many socio-economic and environmental factors.

The distinctive character of Mediterranean agroforestry systems is the complex assemblage of different land covers resulting from a millenary history of man-made modifications (Antrop 2004). Traditional agroforestry systems are still common in many rural areas where intensive agricultural practices cannot be adopted. In these marginal areas, quality of land is poor and it does not allow to adopt intensive agricultural practices (monocultures) and farmers believe that agroforestry is the most appropriate land use system for such kind of marginal lands. In these areas, trees have traditionally served several purposes in the agrarian economy such as the production of fruits, fodder and wood for fuel, litter or timber. In addition, they have amenity value, providing shade and shelter for labourers and livestock, and combat erosion by wind and water. In the last decades the traditional composition and arrangement of Mediterranean landscapes have been significantly changed by urbanization, industrialization, logging, agricultural policies (CAP) and climate change effects (Simoniello et al. 2015). Typical traditional agroforestry systems include high natural and cultural value agroforestry like the grazing in woodland in Dehesas (Spain), in Montados (Portugal) and in Sardinia (Italy); agroforestry for high value tree systems like olive orchards managed at various level of complexity in Italy and Greece (olive trees are typically planted in rows, although they may also be irregularly scattered when groves have been thinned). Oaks, carob, walnut, almond and other fruit trees often form a minor mixed component (Eichhorn et al. 2006).

Mediterranean farmers usually demonstrate awareness concerning agroforestry especially in terms of environmental benefits (biodiversity conservation, carbon sequestration, soil erosion control, landscape improvement) and production potential (income diversity, product quality, business opportunities); but, at the same time, they still perceive the complexity of management (higher level of labor compared with monoculture, difficult of mechanization) as main constraint to their adoption (Camilli et al. 2016). Farmers usually affirm that economic subsides are needed to compensate the complexity of work. Farmers also complain about the complexity of EU policy supporting agroforestry systems: the lack of knowledge, the bureaucracy mechanism, the conflict between Pillar I and II of the Common Agricultural Policy often discourage farmers to apply for grants. In the previous Common Agricultural Policy (2007 - 2013), trees, trees in rows and hedges reduced the Single Farm Payment because they reduced the eligible farm size (Pisanelli et al. 2014). In the current program (2014-2020), there is a discussion concerning the maximum number of trees that are allowed in order to keep the direct payment eligibility. In a recent study that tried to frame factors behind uptake of agroforestry practices based on interviews and farmers, Rois-Díaz et al. (2017), found that farmers and stakeholders perceive that the wild fauna (especially wolf) is becoming a huge problem in Mediterranean area since farmers are forced to limit the free-grazing time (especially sheep) to avoid animal attacks. Consequently, the production, both in quantitative and qualitative terms (e.g. of meat and cheese) is reduced. Farmers perceived that a label or certification would be appropriate response to compensate the high cost of agroforestry products. They are also aware that their farms are often located in a fragile environment and for the last few years, several damages occurred because of heavy rain (flooding and landslides). Farmers who do not implement agroforestry practices believe that it could play an important role in preventing natural disasters due to extreme events.

Similar to the study mentioned above, the aim of this research is to determine what are the most relevant criteria behind uptake of different agroforestry practices in the Mediterranean biogeographical region. This was done by applying a series of surveys to experts in the field of agroforestry or a related field and analysing the results using the Analytic Network Process (ANP). The model was used to examine how a farm 'typical' for that region could improve its management system by implementing one of five agroforestry management options, namely: i) high natural and cultural value agroforestry systems, ii) agroforestry with high value trees, iii) agroforestry for arable systems, iv) agroforestry for livestock systems and v) no agroforestry system. The model comprised separate benefits, costs, opportunities and risks sub-networks, with a total of 35 criteria.

5.3 MATERIAL AND METHODS

Analytic Network Process is a multi-criteria decision making model. It is based on pairwise comparisons of its elements, where any element of the model can be related to any other part of the model. The full ANP model has separate 'sub-models' (sub-matrices) for Benefits, Opportunities, Costs and Risks (BOCR). The decisions are based on a defined description of a situation, and must entail a limited set of discrete alternative decisions.

Mathematically, the model is presented in form of different matrices where all elements of the model are present both in rows and columns. First and basic mathematical representation of the model is the 'unweighted supermatrix', in which the columns are the 'senders', and the rows are 'receivers' of the influence relation in the comparison of the model's elements (Saaty and Vargas 2006; Saaty 2008). Unweighted supermatrix can be separated into different symmetrical sections called components, describing different segments of the decision model. These components can be assigned with different weights, where the multiplication of unweighted supermatrix with these weights produces weighted supermatrix. If elements of unweighted supermatrix are not separated into different components, then it is the same as the weighted supermatrix. Multiplication of weighted supermatrix by itself multiple times until limit of the sum of all the powers of the matrix is reached (i.e. until all the columns are the same) yields limit supermatrix. The results of the model, i.e. the priorities of discrete alternatives are stated in respective rows for each alternative in the limit supermatrix.

When the judgments, i.e. pairwise comparisons are made, they are stated in a form of a question. A classical form of a question would be: What is the relative importance/influence of the elements A and B ('children' nodes) on element C ('parent' node)? The answers would be presented in a textual form matching to the Saaty's Fundamental scale (ranged from 1 – equal importance to 9 – extreme importance, where reciprocals values are used for inverse comparisons).

If the judgment in a pairwise comparison is that its elements are of equal importance, then the selection would be value of 1, where both elements would be assigned with priority 0.5. If one element is extremely more important than the other, than the selection would be 9 in favour of the dominant element. Their assigned priorities would be 0.9 for the dominant element, and 0.1 for the other one. Saaty (2008) discourages the usage on values greater than 9 on the Fundamental scale. For a model with multiple sub-matrices, overall priorities are calculated by relaying the respective BOCR priorities through a single formula, where the most frequently used ones are multiplicative (B*O/C*R) and additive negative (w*B+w*O-w*C-w*R) formula. Priorities obtained by multiplicative formula represent best short-term results, and priorities obtained by additive negative formula represent best long-term results (Saaty and Ozdemir 2005). Other formulas for aggregation of overall priorities that are frequently used (Wijnmalen 2007) are multiplicative with weights as powers ((Bw *Ow)/ (Cw*Rw)) and additive with weights as coefficients (w*B + w*O + w*1/C + w*1/R), where values of 1/C and 1/R are normalized to a 0-1 range.

Model design

The model was designed with an objective to assess the priorities of main types of agroforestry practices in the Mediterranean context within the framework of different economic, social and environmental criteria. Senior experts in agroforestry were asked to describe typical farm and farm management scenarios, which became the basis for the decision making models. The description of the decision scenario is presented by Table 1.

Table 1. Management scenario of the ANP model

FARM DESCRIPTION

The decision to adopt agroforestry practice or not is considered by a farmer which owns a typical farm in the Mediterranean region. The farms size is 200 ha, on altitude between 0 and 600 m asl, precipitation from 500 to 660 mm yr-1, average annual temperature of 11 C° on cambisol soil with the following crop types: barley, wheat and alfalfa. A small forest (15h) of Quercus ilex belongs to the farm. The mechanization is possible in the area due to the extensive flat lands. The owner is 55 years old, owns the farm, has lower level education, and implements traditional farming practices.

MANAGEMENT ALTERNATIVES

1. Implement High natural and cultural value agroforestry system

The farmer may consider adopting a high nature and cultural value agroforestry practice in these systems. The farmer considers including hedgerows and forest strips to promote biodiversity and an increase of crop resilience and adaptation to climate change. The chosen woody species are Quercus ilex and Juniperus thurifera.

2. Implement High value tree systems

The farmer considers adopting an agroforestry practice with high value trees. The farmer is looking for ways to increase the profitability of his farm and at the same time to improve ecosystem services. Part of the land will be planted with Prunus and Juglans trees (max 100 tree per ha to make the land eligible for the CAP). A forest management plan will be made with the objective to optimize high quality timber production. This will include a thinning of the stands in the mid-term, before final felling, pruning is done every year.

3. Implement Agroforestry for arable systems

The farmer considers adopting an arable agroforestry system. The farmer is looking for ways to diversify farm production to ensure a more stable income base for the farm. The farmer decides to plant fast growing trees like poplar (Populus) in the arable land up to a maximum density of 100 trees per ha to make the land eligible for the CAP. The tree rows are planted at 12 m of distance. Along the rows the poplars are planted at 9 m distance.

4. Implement Agroforestry for livestock systems

The farmer considers adopting a livestock agroforestry system. The farmer is looking for ways to diversify farm production and he considers the possibility of combining meat (lamb and beef), arable and forage crops to overcome season pasture deficits. Hedges of mulberry (Morus alba) trees with high quality forage value would be planted and sheep would be introduced in part of the arable land. Cattle will be introduced in the small forest of Quercus ilex. One large investment the farmer has to make is to fence the farm.

5. Do not implement agroforestry system

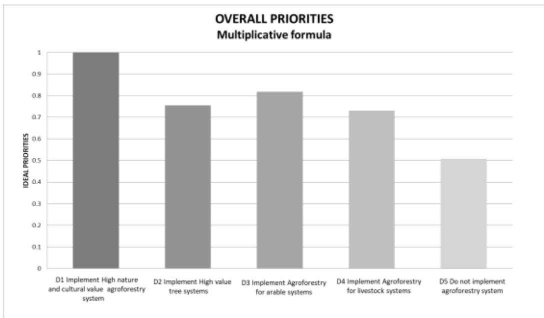
The farm continues with the same management regime as before, and no changes are introduced.

Ten senior agroforestry experts were then asked to define a preliminary list is social, environmental and economic criteria that might affect agroforestry practices. These results were then presented and discussed in a workshop of the AGFORWARD project with 22 participants. They have all filled-in another questionnaire where the list of criteria was improved and their relations were drafted. A draft ANP model was designed and sent back to the experts for comments in a form of a questionnaire. Subsequently, the improved model was send back again to the participants to assign pairwise comparisons between the elements of the model. Respondents also commented on the importance of individual criteria, their meaning and potential overlap, and also on the general structure of the model. The main comment was that the model's complexity needs to be reduced. Based on this feedback, the number of criteria was decreased from 54 to 35. Respondents received one more questionnaire in the end, which focused on 'critical' comparisons, i.e. comparisons in which opinions of the respondents were divergent. The criteria for selection of a 'critical' comparison was that its value in priority vector for at least one respondent diverges by value 0.194 from the arithmetic mean of the priority, which reflects summed value of mean and one standard deviation of the priority. This questionnaire had 26 out of total of 273 direct comparisons in the model. Although varying number of respondents were engaged in different stages of the model design, it would be prudent to state that it was constructed with an input of eight decision makers, as this is a minimum number of people that have been involved in a single step of the model design.

After this questionnaire, there were no more any 'critical' judgments, and the design of the model was finalized. At this point calculation of final priorities and sensitivity analysis was performed. A summary of this analysis was given back to the respondents, and they were asked to provide their feedback, describing and commenting (both qualitatively and quantitatively on a Likert scale) to what extent are the presented results an adequate representation of a real-life situation. The final model is a full BOCR model with 35 criteria, where Benefits sub-network has been further disseminated into three clusters that represent environmental, economic and social benefits. The overview of criteria is presented by Table 2 in the results section.

5.4 RESULTS

Overall ideal priorities as obtained all four formulas (Figures 1-4) show precedence of High natural and cultural value agroforestry systems (D1) over all other alternatives. However, the best long-term results as obtained by additive negative formula (Figure 2) differs from other three calculations as it greatly enhances the relative priority of high natural and cultural value agroforestry systems over all other management alternatives, where arable agroforestry (D3) and no agroforestry (D5) have a negative priority.



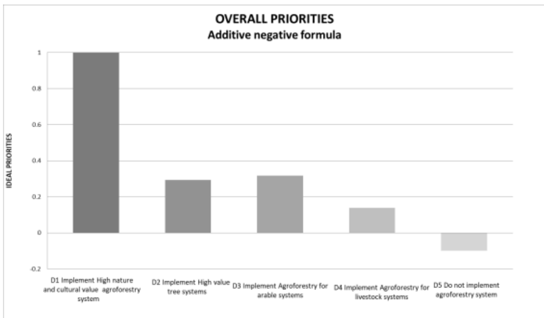
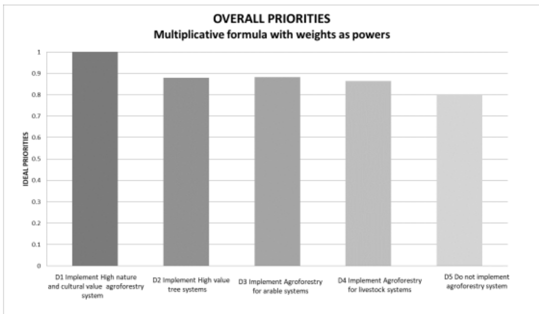


Fig. 1 Overall ideal priorities for the Mediterranean region model obtained through multiplicative formula

Fig. 2 Overall ideal priorities for the Mediterranean region model obtained through additive negative formula



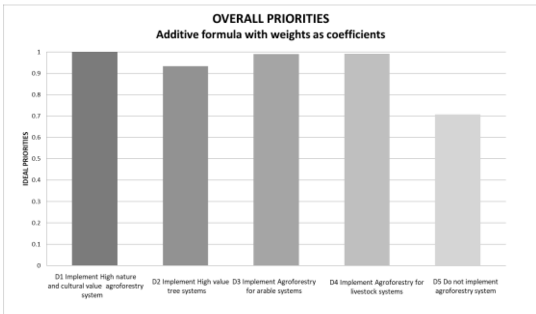


Fig. 3 Overall ideal priorities for the Mediterranean region model obtained through multiplicative formula with weights as powers.

Fig. 4 Overall ideal priorities for the Mediterranean region model obtained through additive formula with weights as coefficients

The main feedback from the experts on the comparison of different management alternatives was that the most important difference between agroforestry practices (D1-D4) and 'classical' farm (D5) is that agroforestry has much more benefits and opportunities but also much more costs, and that this was well reflected in the model (Figure 5). The greatest benefits however, were attributed to High natural and cultural value agroforestry systems (D1), which greatly contributed to the highest overall priority of this system. Do not implement agroforestry (D5) had only moderate benefits and opportunities, relatively low costs but also high risks, which led to a negative overall priority.

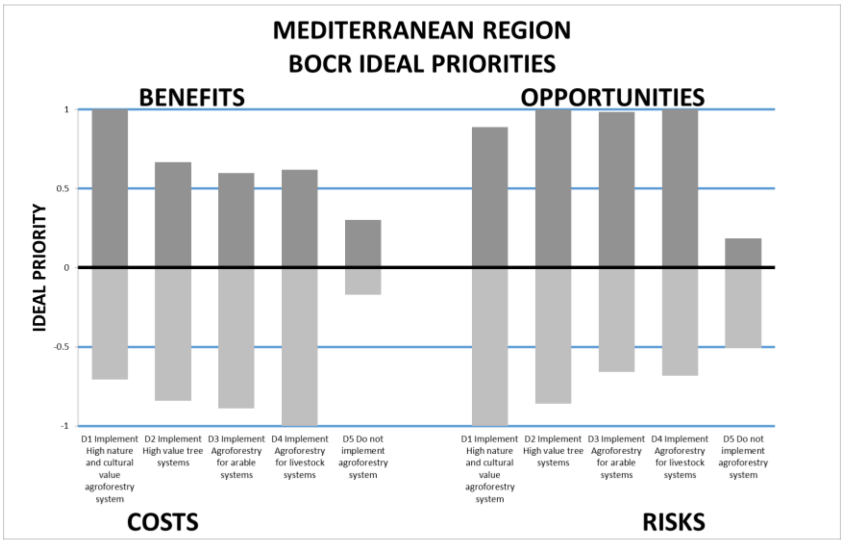


Fig. 5 BOCR ideal priorities for the ANP model

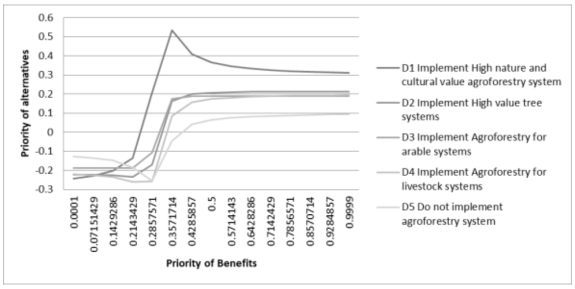
The main criteria (Table 2) seen by the experts for making the decision to establishing an agroforestry system are: lower input of pesticides, improved water quality, production of higher quality crops and timber, lower business risk due to diversification, knowledge and information on agroforestry systems, family tradition, increased labour requirements, competition between crops, trees and animals, higher employment, availability of subsidies, low market opportunities and lack of subsidies.

Table 2. Priorities of criteria normalized by cluster for the Mediterranean region model. Criteria with highest priority in cluster is marked with dark grey, and the criteria with second highest priority is marked with light grey.

CRITERIA	PRIORITY NORMALIZED BY CLUSTER	CRITERIA	PRIORITY NORMALIZED BY CLUSTER	CRITERIA	PRIORITY NORMALIZED BY CLUSTER
Environmental Benefits (B.EV.)		**Economic Benefits (B.EC.)**		**Costs (C)**	
1 Lower input of pesticides and/or fertilizers	0.31847	1 Longer production period	0.04521	1 Additional investments required (mechanization and infrastructure)	0
2 Reduce soil erosion	0.05886	2 Lower labor cost	0.02531	2 Increased labor requirements	0.53054
3 Resilience in farming	0.04556	3 Lower business risk due to diversification	0.45218	3 Competition between crops, trees and animals	0.46946
4 Fire prevention	0.0013	4 Higher revenues	0.00305	**Opportunities (O.)**	
5 Animal health and welfare	0.00407	5 Production of higher quality crops and timber	0.45532	1 Presence of AF systems in vicinity	0.0283
6 Improved water quality	0.24617	6 Manure capture	0.01893	2 Expected higher income	0
7 Improved flood regulation	0.23578			3 Assistance from extension services	0.2412
B.EV.8 Improvement of soil quality	0.07561			4 Availability of subsidies	0.37882
9 Improvement of biodiversity	0.01418			5 Local supporting policy (e.g. PES)	0.03985
10 Improvement of climate	0	**Social Benefits (B.S.)**		6 Supporting rural development of the area	0
11 Improvement of landscape aesthetics	0	1 Family tradition	0.42313	7 Increased land value	0
		2. Ownership of the plot	0.02462	8 Higher employment	0.31106

		3. Knowledge and information on agroforestry systems	0.55225	**Risks (R.)**	
				1 Long term commitment when receiving a subsidy	0
				2 Lack of subsidies	0.45305
				3 No added value for AF products	0
				4 Low market opportunities	0.54695

In order to test the robustness of the results, a sensitivity analysis has been performed on the level of sub-networks (Figures 6-9) and individual criteria (Figures 10-14) as based on additive formula.



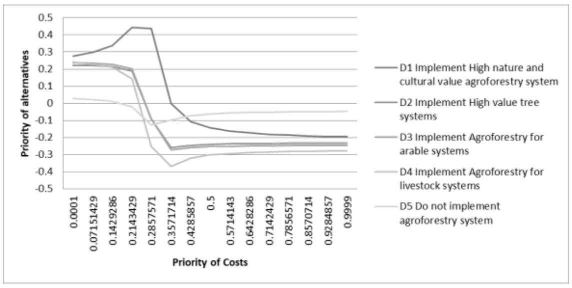
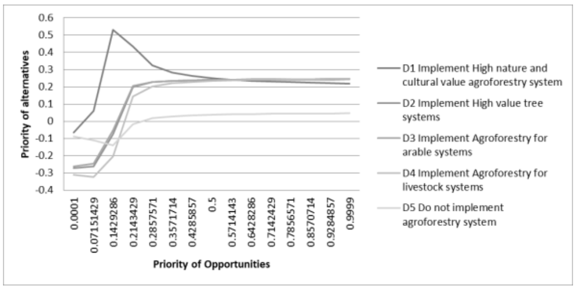


Fig. 6 Sensitivity analysis of Benefits sub-network for the Mediterranean region model

Fig. 7 Sensitivity analysis of Costs sub-network for the Mediterranean region model



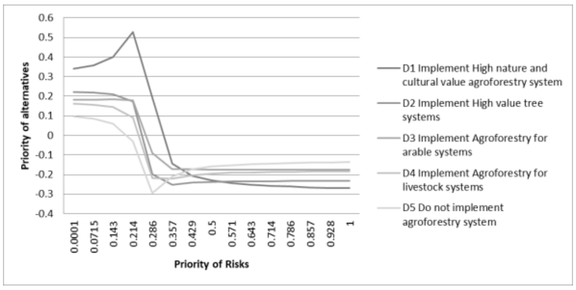
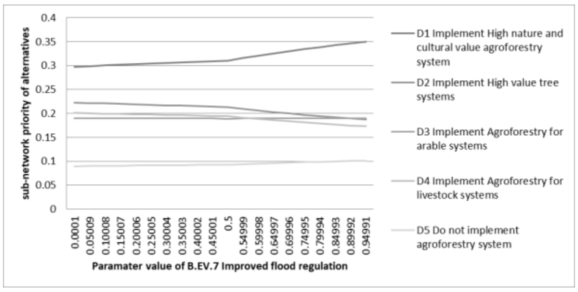


Fig. 8 Sensitivity analysis of Opportunities sub-network for the Mediterranean region model

Fig. 9 Sensitivity analysis of Risks sub-network for the Mediterranean region model

Sensitivity analysis on the level of sub-networks shows increase of the priority of alternatives with increase of value of benefits and opportunities, and decrease of priorities to negative values with the increase in costs and risks. Although the ratio of priorities show sensitivity to weights of sub-networks, they demonstrate strong rank-preservation, which is of great importance to the interpretation of result. The only exception is the rank-reversal in the case of costs-sensitivity, demonstrating that No agroforestry (D5) is the preferred alternative when the importance of costs is high.

Node-level sensitivity graphs have been shown in the figures below only for criteria in which sensitivity analysis has caused rank-reversal on the level of respective sub-network; and that has occurred for 5 out of 35 criteria, which indicates relative stability of priorities to the changing values of individual criteria.



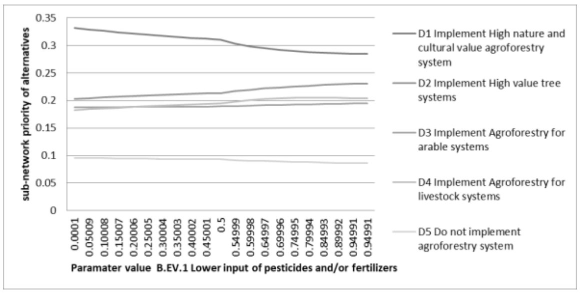
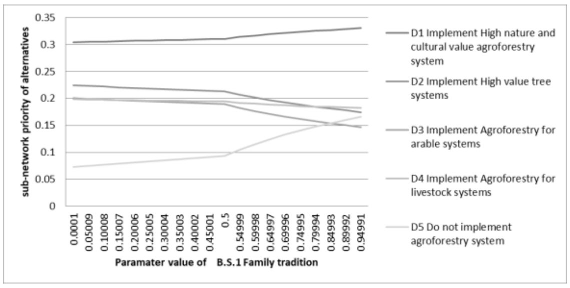
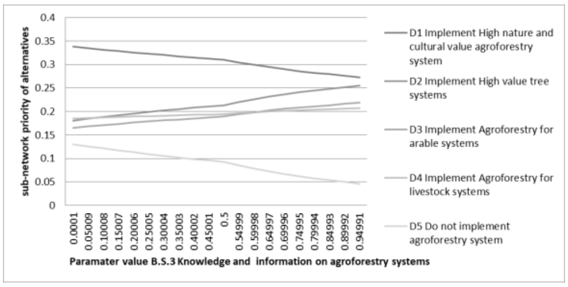


Fig. 10 Node-level sensitivity analysis of Improved flood regulation criteria in the Benefit sub-network

Fig. 11 Node-level sensitivity analysis of Lower input of pesticides and/or fertilizers criteria in the Benefit sub-network





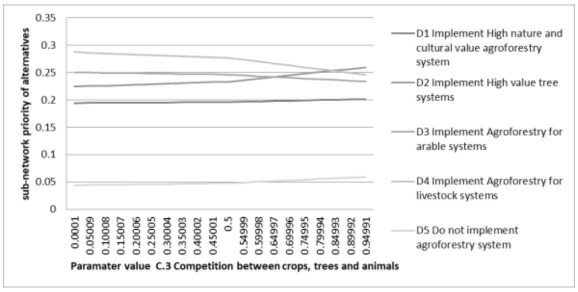


Fig. 12 Node-level sensitivity analysis of Family tradition criteria in the Benefit sub-network

Fig. 13 Node-level sensitivity analysis of Knowledge and information on agroforestry systems criteria in the Benefit sub-network

Fig. 14 Node-level sensitivity analysis of Competition between crops, trees and animals criteria in the Costs sub-network

This stability of results can also be seen as rank-reversal occurs only on relatively high values of individual criteria, and even in those cases does not affect the rank of high nature and cultural value agroforestry systems (D1) and of the no agroforestry alternatives (D5). The only exception is that with increase of family tradition the benefits of no agroforestry alternative exceed the benefits of arable systems (D3). In the follow-up validation questionnaire respondents were given the results of the analysis, and asked ‘Given your knowledge on agroforestry systems and with respect to the farm management scenarios, do you agree or not agree that the presented result is an adequate representation of a real-life situation?’ This question was posed on a nine-point Likert scale, and asked separately for overall priorities under each aggregation formula, and separately for priorities under each sub-network. The mean value of answer was 7.62, which falls under ‘Strongly agree’ category.

5.5 DISCUSSION

In Europe, Graves et al. (2008) found that farmer perceptions regarding silvoarable systems varied substantially between Atlantic and Mediterranean areas of Europe. Trees were more numerous on Southern European than on Northern European farms. Most farmers were willing to use silvoarable systems if they were profitable, but the form of agroforestry envisaged varied. The farmers also identified a number of risks, and were concerned that the long-term nature of agroforestry could leave them exposed to reductions in the value of timber and felt some form of insurance or subsidy would be required to promote adoption. Concern also existed regarding long-term eligibility of the land to EU subsidies and agri-environment support measures.

The Mediterranean region model gave a low overall priority to Do not implement agroforestry (D5) and a high priority to high natural and cultural value agroforestry (D1). This is very well reflected in the actual distribution of agroforestry as the countries belonging to the Mediterranean zone have generally the highest agroforestry cover in Europe, ranging from 10.9% of the UAA in Italy to about 40.9% of the UAA in Cyprus (den Herder et al. 2016). Lower input of pesticides and fertilizers, improved water quality, improved flood regulation, were perceived as the most important environmental benefits. These finding are consistent with previous research with farmers where benefits of agroforestry were largely viewed as environmental (Graves et al. 2008). Lower business risk due to diversification and production of higher quality crops and timber were seen as the most important economic benefits. This is consistent with the findings of Camilli et al. (2016), who observed that Italian farmers similarly thought that one of the most important benefits of silvopastoral systems was the production of high quality products, which meet the consumer demands. The results from the ANP mirror the findings of previous research described above relating to such farmers' perceptions of benefits in highly mechanised systems. The application of livestock agroforestry and arable agroforestry for example was beneficial in relation to costs setting it apart from high value tree agroforestry. Again mirroring the literature (Sereke et al. 2014; Camilli et al. 2016), increased labour requirements and competition between crops, trees and animals were viewed as the most significant costs (Table 2). The availability of subsidies and assistance from extension services would create the greatest opportunities for the system, but low market opportunities and lack of subsidies were seen as the greatest risks. This is confirmed by an Italian case study by Camilli et al. (2016), where the farmers expressed the need for assistance by extension services in field trails and where the farmers complained that the bureaucratic complexity of the Common Agricultural Policy discourages them from applying grants for establishing new agroforestry systems. Pannel (1999) has suggested that long term technologies face several challenges when proposed as innovations. Firstly, the farmer must have the information that the alternative system exists, secondly he must be satisfied that it can be trialled, thirdly perceive that it is worth trialling, and fourthly consider that it meets objectives, particularly profit. These conditions are not easily obtained in long-term systems. For example, trialling silvoarable systems successfully to test for profit is difficult, and the initial constraints and disadvantages, such as high initial investment costs and increased difficulty of machine operations are readily apparent, but the full benefits may only be observed over a long period.

The usage of different formulas for aggregation of overall priorities has caused strong change in the ratio of alternatives' priorities; and in this light it is more prudent to look at their rank and not the ratio. However, usage of different formulas has also caused rank reversal, where priority of arable systems (D3) became lower than of other agroforestry practices. This is one of the general problems of multi-criteria decision making (Triantaphyllou 2000), and it occurs in ANP as well (Kong et al. 2016), where in this case they have occurred due to weights of individual BOCR sub-networks. However, results from three other formulas for aggregation of overall results and the sensitivity analysis in general show robustness of priorities to changes in the calculations, with the primacy of high natural and cultural value agroforestry over other management alternatives.

5.6 CONCLUSIONS

An important outcome of this study was that the environmental benefits, product diversification and quality were perceived among the most important decisive factors when farmers consider establishing an agroforestry system, but that social factors such as family tradition play an important role as well. In addition, farmers need the assistance from extension services and the lack of subsidies or the complicated application procedures can be an important barrier in the establishment of new agroforestry systems. With an understanding of these connections, policies could stimulate learning from peers, relatives and extension services and promote cooperation between like-minded farmers to conduct environmental friendly agroforestry practices producing more diverse quality products. Policies can stimulate knowledge exchange between farmers and extension workers to raise awareness on the benefits of agroforestry and how this might be related to traditional land use. In order to do so, the training curricula of extension service workers need to be updated as these not always include education on agroforestry and they are seldom trained to promote these practices to the farmers. These findings match the results from Rois-Díaz et al. (2017) based on interviews to farmers implementing agroforestry across Europe, where tradition, diversification of products and learning from others are the main drivers for adoption of agroforestry practices. At the same time, it is necessary that the application procedures for agri-environmental subsidies and the establishment of new agroforestry systems are simplified and made more clear, and that extension services are also able to provide assistance in the application procedure to the farmers, in case they are interested in agroforestry or other ecosystem-based farming systems. Sensitivity analysis indicated to these findings that when the importance of costs is pronounced, the most viable management option is not to implement any agroforestry practices. These pronounced practical costs also are reflected in the relative minor share of agroforestry compared to overall agricultural practices. Supporting policies and other factors such as security of agri-environmental subsidies and adequate attention from extension services that can decrease the practical 'costs' of agroforestry and thus contribute to their increased uptake; as these are the factors that have direct impact on the farmers while same cannot be stated for the numerous environmental benefits of agroforestry.

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6 RESULTS. CHAPTER 3. AGROFORESTRY IN THE EUROPEAN COMMON AGRARIAN POLICY

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The contribution of the author of this thesis to this article is the literature review, results interpretation and co-writing of the paper.

6.1 Abstract

Agroforestry is a sustainable land management system that intends to be promoted in Europe ensure adequate ecosystem services provision in the old continent (Decision 529/2013) through the Common Agrarian Policy (CAP). The promotion of the woody component of Europe can be seen in the different sections of the CAP linked to Pillar I (direct payments and greening) and Pillar II (rural development programs). However, agroforestry is not recognized as such in the CAP, with the exception of the measure 8.2 of the Pillar II. The lack of recognition of agroforestry practices within the different parts of the CAP will reduce the impact of CAP activities due to the lack of thinking of best combinations to maximize productivity from those lands where agroforestry should be promoted, considering both spatial and temporal scales. A better approach, such as management plans, should be developed in order to guarantee the full Pîllar I payment of agroforestry established in agricultural lands.

Key words: Pillar I, Pillar II, Greening, Rural Development Programs, Cross-Compliance

6.2 Introduction

The Common Agrarian Policy (CAP) is the most important driver of agricultural management and sustainability in the European Union. CAP represents around the 40% of the European Union budget being the expenditure (in current prices) doubled from about 30 billion Euros in 1990 to the current 60 billion Euros (CAP 2007-2014). he European Common Agricultural Policy (CAP) has evolved from its initial inception in 1962 when it covered six countries. In 1973, the inclusion of the UK, Ireland, and Denmark increased the total to nine. Following additions were made in 1981 (10), 1986 (12), 1995 (15), 2004 (25) (Figure 8). The inclusion of Romania and Bulgaria in 2007 brought the total to 27, and finally they amounted 28 due to the incorporation of Croatia in 2013 and will be 27 after the Brexit agreements. The CAP now has a direct impact on 14 million farmers with a further 4 million people working in the food sector. One of key reforms of the CAP occurred in 1992, when the "MacSharry" reforms sought to limit further increase of the cost of the CAP, and started the shift from product support (through prices) to coupled direct payments (through income support). The distribution of the payment to different EU target aims has also changed with coupled payments, exports, refunds and market support measures reduced or removed completely. The year 1992 also saw the introduction of the first directives that allowed European support for the planting of forest trees on agricultural land. . The Agenda 2000 reforms, signed in Berlin in 1999, emphasized the division of the Common Agricultural Policy into a "first pillar" (based on single farm payments) and a "second pillar" focused on rural development measures. Following the CAP reform in 2003, payments were decoupled from the production of a specific product, with farmers instead receiving payments based on a set amount per hectare of agricultural land. The CAP has also aimed to become more environmentally-oriented. For the 2007-2013 period, Pillar I across the EU27 was worth just over three times as much as Pillar II. However there were differences between the CAP budget of the old and new Member States. Whilst the level of expenditure was relatively balanced in the EU-12 (where the level of expenditure on both Pillars is almost the same), the EU-15 receives five times as much for Pillar I as Pillar II. For the 2014-2020 period, rural development and environmental issues account for close to 24% of the total CAP budget.

Nowadays, the CAPis designed to ensure food production within the sustainable FAO principles. It is written by the European Commission and has to be approved by the EU political bodies (Parliament and Council of Europe). Once approved the CAP is implemented during a period of 7 years. CAP is based on two main regulations that are commonly called Pillar I and Pillar II that were developed by Regulations 1307/2013 (EU 2013a) and 1305/2013 (EU 2013b) for the 2014-2020 Commitment period. Global budget of CAP is EUR 281.8 billion to the first pillar of the CAP; EUR 89.9 billion to rural development (EU 2011). Pillar I is completely funded by the EU and initially linked to land productivity, while Pillar II is associated to environment and co-funded by the Member States, which fosters the impact of the CAP in Europe. Getting paid by any of the Pillars is linked to the accomplishment of some rules in the so called Cross-compliance aiming at fulfilling the minimum requisites of sustainability dealing with water quality or livestock health and welfare, among other aspects. Getting paid by Pillar 1 is also linked to the eligibility concept. Eligibility fulfillment rules is associated to the use of land permanent grasslands, arable and permanent crops. The requisites for farmers to be paid from Pillar II are established by each member state based on their own interests from a productive and environment point of view. Pillar II is composed of Regional and National Rural Development Programs that enhance environment but also livelihood from farmers. This paper aims at analyzing the promotion of agroforestry practices within the cross-compliance, Pillar I and Pillar 2 of the CAP at EU level for the period 2014-2020.

6.3 MATERIALS AND METHODS

The analysis carried out in this paper is based on the literature review of the main CAP legislation framework for Pillar I (Regulation 1307/2013) (EU 2013a) and Pillar II (Regulation 1305/2013) (EU 2013b) as well as the accompanying and transposed legislation like the delegated acts and 88 out of the 118 Rural Development Programs of the period 2014-2020, currently existing in the CAP. Different documents and reports presented by the European Commission in the Civil Dialogue Groups and in the European Network for Rural Development were also searched within the European Commission web page thanks to the participation of EURAF (European Agroforestry Federation (www.agroforestry.eu) in the meetings.

The paper analyses how the presence of woody vegetation is promoted within the current European CAP framework (period 2014-2020) besides the agroforestry specific measure of the Pillar II that the CAP integrated since 2007. Agroforestry promotion is evaluated in the different sections of the CAP that has to been fulfilled by the farmers, such as (i) cross-compliance that have to be accomplished as a prerequisite to get the payments linked to Pillar I or Pillar II, (ii) direct payments that include on one hand eligibility and on the other the greening with norms necessary to get paid the Pillar I and (iii) the Pillar II. In all these sections, the CAP allows to choose the activities for the implementation by the National Programs, which on turn develop strategies linked to the Partnership Agreement. The selected options may vary or are expanded as CAP is running within a specific commitment period. The evaluation was carried with the available information of the year 2017 and backwards.

6.4 RESULTS

Agroforestry definition

Within the European Union (EU), Article 23 of Regulation 1305/2013 (EU 2013b) defines agroforestry systems as "land use systems in which trees are grown in combination with agriculture on the same land." However, woody perennials are considered by the European Commission in the deployment of the Regulation 1305/2017 where Measure 8.2 (EU 2014) defines agroforestry on agricultural land as "Agroforestry means land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same parcel of land management unit without the intention to establish a remaining forest stand. The trees may be arranged as single stems, in rows or in groups, while grazing may also take place inside parcels (silvoarable agroforestry, silvopastoralism, grazed or intercropped orchards) or on the limits between parcels (hedges, tree lines)". The EU currently indicates that arable land, and therefore agroforestry on such land, will not be eligible for direct payments if it has more than 100 trees per hectare indicated by Regulation 640/2014 (Mosquera-Losada et al. 2016b), but it allows member states to select tree densities if local practices are implemented on permanent grassland. The definition given by the European Commission is in line with the AGFORWARD (AGroFORestry that Will Advance Rural Development) project definition, as it specifies that the concept of "trees", is linked to woody perennials (therefore "trees and shrubs" and secondly it suggests that agroforestry on arable land may be limited by the number of trees per hectare.

Cross-compliance

Farmers get paid the direct payments and greening as well as Pillar II funds, after fulfilling Statutory Mandatory Regulations (SMR) and Good Agricultural and Environment Condition (GAEC) which is generally known as Cross-compliance (former conditionality). SMR refers to EU Directives and Regulations linked to public, animal and plant health, identification and registration of animals, environment and animal welfare. Agroforestry is able to fulfill directly the first three measures (nitrate vulnerable zones, biodiversity dealing with birds and habitats) of the SMR but also the rest can be improved by the sustainable agroforestry practices (i.e. the quality of feed and food).

GAEC within the period 2014-2020 currently includes options related to water and soil and carbon stocks -where agroforestry can play a role as sustainable agricultural practice but also as GAEC-7 linked to the retention of landscape features. Landscape features includes, among others, woody vegetation being hedges, trees in line, in group or isolated directly related with AF practices, among others like ponds, terraces, field margins etc… The AF practices linked to GAEC7 are of high interest in some countries as they avoid problems related with winds or flooding and increase biodiversity.

Pillar I

Direct payments

CAP establishes three different types of land in order to evaluate if they are suitable to receive basic payments and greening through eligibility: arable land, permanent grassland or permanent pasture and permanent crops.

Arable lands

Eligibility of arable lands is limited by the Delegate Act 640/2014 (EU 2014a) to those lands with a tree density below 100 trees per hectare. This specific constrain makes difficult for farmers to include trees on their arable land, mainly when they have small plots. The conditions of those trees, defined as isolated trees, are provided in the Delegated Act 639/2014 (EU 2014b) as those with a minimum crown diameter of 4 meters, which means a tree cover of 1256 m2 per hectare (12.56%) if the 100 trees per hectare rule is considered. If trees are grouped, the maximum area allowed for woody vegetation is even lower as CAP allows the 10% of the hectare (1000 m2 per hectare) to get paid. Regarding the hedges or hedgerows, the regulation protects those already existing with width up to 10 meters (regulation act 639/2014 (EU 204b)), but only 2 meters width can be claimed for payments as eligible land even if the member state protects wider hedges (DEFRA 1997).

Permanent grassland or permanent pasture

Following the definition given in the Regulation 1307/2013 (EU 2013a) permanent grassland or 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 (ELP) where grasses and other herbaceous forage are traditionally not predominant in grazing areas." including therefore agroforestry as woody vegetation is admitted", on which no predominant herbaceous grasslands can claim full payment if ELP is selected by the European Member states. Those countries that activate ELP, therefore payments for non-predominant herbaceous permanent grasslands are Germany, Spain, and Sweden, Greece, France, Hungary, Italy, Cyprus, Portugal and United Kingdom. However, all non-predominant herbaceous permanent grasslands may claim full payment if grazed thanks to the implementation of the OMNIBUS regulation after 2018 (European Council 2017).

Permanent crops

Permanent crops are defined by the commission as non-rotational crops other than permanent grassland that occupy the land for five years or more and yield repeated harvests, including nurseries and short rotation coppice. For permanent crops, the tree densities given for arable lands eligibility did not apply and the combination with crops are allowed. If fruit trees are combined with grazing, this type of land use falls within the silvopasture concept and again no restrictions of fruit tree density are considered. Permanent crops are those listed in the Annex 1 of 1308/2013 such as apple, pear, apricot, peach, nectarines, orange, small citrus, lemon and olive trees as well as vineyards for table production as the woody component.

Greening

Greening is the payment for agricultural practices beneficial for the climate and the environment, and as part of the Pillar I payments, represents the 30% of the direct payment value received by farmers Greening as happen with the cross compliance, includes Landscape Features as an option to fulfill the greening requirements by farmers but also the option of selecting agroforestry. At least one type of Landscape Feature has been initially selected by 24 Member states, but it does not mean that trees in line, copses or isolated trees are selected, which makes difficult the evaluation of the impact of the Greening measure. This is because Landscape Features includes other options such as ponds, terraces, field margins etc… that are not related to woody vegetation. Moreover, even though the countries have done an initial selection, they may not activate them when CAP is implemented.

Unfortunately, greening only affects to the 40% of the Direct Payment beneficiaries of Europe, mainly due to the small size of the farms, which receives greening payment per se. The percentage of total agricultural area subject to at least one greening obligation (crop rotation, permanent grassland preservation and Ecological Focus Area) is lower in South (Greece, Italy, Malta, Portugal) than in North European countries like Germany or Latvia. The most selected option of Ecological Focus Areas (EFA) by the EU member states is nitrogen fixing crops (35 to 46%), followed by catch crops (15-27%) and land lying fallow (21 to 35%), that represents the 94% of the area that fulfills EFA requirements. The selection of any of these three options among others, included agroforestry, is probably because they were the most easy to implement by farmers. Agroforestry was not implemented yet and landscape features were only used in around 4.34% of the land claiming greening. It is expected a great diversification in the EFA choices by farmers in the forthcoming years, and hopefully woody vegetation will be more used.

Pillar II

Table 1 shows the measures promoting the woody component in agricultural lands or agricultural activity linked to the woody component in the evaluated rural development programs of EU, while Figure 1 represents the number of measures linked to agroforestry implemented in the evaluated EU regions. Most of the CAP 2014-2020 programs have been approved during the year 2015, so they were only partially implemented in 2016. To carry out this evaluation we have read the 88 Rural Development Programs (RDP) implemented in Europe and organize them based on the activities they finance that are linked to agroforestry practices (silvopasture, silvoarable, forest farming, riparian buffer strips and homegardens). The selected activities are those associated to forest farming agroforestry practices (apiculture), increase of woody vegetation across Europe (forest strips and small stands, hedgerows, isolated trees), those dealing with permanent crops of fruit trees (orchards) and finally those related to silvopasture (forest understory grazing and mountain silvopastoralism). Twenty three measures have been established in Europe that can be associated to agroforestry within the RDP framework, but they do not mention neither agroforestry neither any of its practices in a specific way, with the exception of measure 8.2 from all RDP measures of the CAP 2014-2020. From those, the measure that mostly supported agroforestry is the agri-environment measure number 10.1. Hedgerow (woody component) establishment and management is the most extensively promoted measure linked to agricultural lands all over Europe in number of measures uses, while meadow orchards is implemented in most of regions with one single measure. The specific agroforestry measure 8.2 was intended to be used in only 33 measures out of the 88 evaluated regions, number which will probably be increased in the forthcoming years. In the first year, only 5 Rural Development programs implemented the measure out of the 16 that activated it to those that budgeted it (16), mainly with activities related to the establishment and management of forest strips, small stands, hedgerows and forest grazing.

6.5 DISCUSSION

Understanding CAP at European scale is difficult due to several reasons like (a) the capacity of countries to select between different options within most of the alternatives of the CAP (b) the period of implementation with varying options, usually 7 years, (c) the different environment and socioeconomic situations of the Member States and (d) the varying number of the EU countries implementing the CAP, which has been increased in the last years, causing different degrees of adaptation to CAP. The selection of the alternatives of CAP measures by each Member State delays usually the start of the CAP implementation between one or two years. Member States have to construct their own CAP based on the EU CAP framework and choose among the different alternatives in order to adapt the CAP to their own requirements and environments, which is really an important aspect for agricultural sustainability. Furthermore, accountability as well as modification of CAP rules is always complicated. Besides that, CAP selection may be modified by Member States during the commitment period, and it is usually strongly modified and reviewed at mid term, with important changes, which makes extremely difficult the evaluation of the global period. For example, 2014-2020 CAP, started to implement Pillar I at the beginning 2015, with a extension of the CAP 2007-2013 in 2014 and most of Rural Development Programs set up their initial choices at the end of 2016, after what, farmers can start to fulfill the rules to get paid.

Regarding the difficulties that agroforestry practices have to be promoted at European scale, there are several that deserve to be mentioned. In spite of being the policy concept of agroforestry clearly in line with the AGFORWARD project, FAO (2015) "a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals", or AFTA (2016) "AFTA defines agroforestry as an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock." and USDA (2017) "Agroforestry is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits" in North America, agroforestry is not clearly identified in Europe. The inclusion of "woody perennials" in the current CAP (2014-2020) compared with the previous period (CAP 2007-2013) rather than exclusively "trees" facilitates sustainability and adaptation of farming systems to existing different environments in the EU countries as shrubsbecause of their woody perennial nature, can provide many of the same productive, environmental or social benefits of trees (Mosquera-Losada et al. 2006; Rigueiro-Rodríguez et al. 2009). Moreover, tree definitions vary across countries and trees can also be cultivated in a shrub shape, while providing the same environment and social benefits (Mosquera-Losada et al. 2016a). Therefore, this change of definition facilitated the inventory of agroforestry practices. The current CAP definition shown in the deployment of measure 8.2 is adequate but it should include the two layers concept in a more comprehensive way in order to avoid confusions, because if using fruit trees the crop is on the tree and a two layer is perceptive in Agroforestry definitions. So, the AGFORWARD project propose the following definition: “the deliberate integration of woody vegetation (trees and/or shrubs) as an upper storey on land with an agricultural crop or pasture in the lower story which is consumed by domestic animals on the same parcel of land management unit without the intention to establish a remaining forest stand”. The woody species can be evenly or unevenly distributed or occur on the border of plots. The woody species can deliver forestry or agricultural products and other ecosystem services (i.e. regulating or cultural)” (Mosquera-Losada et al. 2017). Moreover, there is a difficulty to clearly identify the different types of agroforestry practices (silvopasture, silvoarable, forest farming, homegardens and homegardens and hedgerows) within the Pillar I regulation description, being named in several aspects (grazed orchards, landscape features related to buffer strips, isolated trees, hedges…) but not clearly identified as agroforestry. There is a lack of knowledge of the real extent of agroforestry in Europe (den Herder 2017 and Mosquera-Losada 2016a), and besides that, the real extent of agroforestry land funded by the Pillar I of the CAP, which makes very difficult to evaluate the impact of Pillars I and II on agroforestry land use in Europe. For this purpose, the analysis of agroforestry extent at European level provided by den Herder et al. (2017) and Mosquera-Losada et al. (2016c) based exclusively in tree component or in woody component (trees + shrubs), respectively, are the first serious studies to identify agroforestry use and practices in Europe. However and due to the lack of data, researchers are not currently able to know which part of these agroforestry practices are linked to the CAP payment. The first step to improve agroforestry policy in Europe is to identify the land where it is applied and how policy modifies the implementation to create tailor-made agroforestry practice measures according to the needs of specific regions and the ecosystem services they should deliver. Cross-compliance deals with measures of already existing woody component in arable and pasture lands, but not with the increase or real promotion of them. The increase of the extent of use of agroforestry practices should be based on a more flexible strategy pursuing to obtain products from woody vegetation while implementing sustainable practices, within the circular economy and bioeconomy concept. In general, and when considering the eligibility of an arable land no more than a 10% of the arable land is allowed to have already existing woody component, which has been improved from the last CAP 2007-2013 (when only a 5% was allowed). However these rules are still not enough to improve productivity and resilience of European arable systems as the tree density is not linked to the mature tree concept and most of the Member States takes this density as a limit for any new tree plantation accomplished in the European Union. Crown diameter above 4 meters of diameter, can be considered in most cases mature trees, but trees with less than 4 m of diameter are not protected even if they are essential to ensure long term sustainability of isolated trees. The 50 and 100 tree limit given for arable land in the previous (2007-2013) and current (2014-2020) caused destruction of trees, mostly in those small plots of the farm, in both already paid lands and in those lands that farmers intend to include for the CAP payments in the future in order to guarantee payments and reduce burden. Hedgerows larger than 2 meters are not generally considered eligible by the EU, even if they are protected, which makes that farmers relates them with a reduction of the CAP funds in spite of the ecosystem services they deliver and reduce the size, if not destroy them. However, alley cropping or silvoarable practices with short rotation coppices are allowed and fully eligible in the current CAP, but not promoted at all or even specifically mentioned. The woody vegetation of permanent pasture has been protected at some extent by those countries where Established Local Practices are applied. However, there are still countries that decided not to make eligible pastures that are dominated by woody vegetation by not opening the option of the Established Local Practices limiting the positive effect that woody vegetation has to feed animals during the drought period of the summer. This may change with the implementation of the OMNIBUS Regulation (European Council) after 2018. Another aspect that makes difficult woody vegetation to survive the CAP is that it does not consider tree species, tree density is taken as a strong limit factor to reduce payments within the CAP as it is supposed to reduce agricultural activity. The tree density criterion has at least three main drawbacks. The first one is that the limiting factor for radiation to reach understory is not the tree density but tree cover, that can nowadays easily measured thanks to the use of satellite images, but not considered by the CAP. The second drawback is linked with the general assumption that the reduction of radiation reduces understory production, as there are some crops better adapted and more efficient under shade conditions that even increase productivity (i.e. the active principle “rosmarinic acid” extracted from Melisa officinalis L., that is increased under shade because the maximum productivity and quality of the rosmarinic acid is linked to the previous flowering period, and shade delays flowering period, therefore increasing the active principle production per unit of land). On this regard, adequate genetic selection of crop varieties able to grow up under shade conditions should be developed as most of the varieties already existing in the market where selected in open conditions. The third drawback of the tree density criterion is the lack of link of this tree density to the temporal dimension, besides of the spatial dimension. The presence of trees in a plot is essential to extend growing season as the effect of the droughts and extreme heats is less prone to reduce production if trees are present. This is key to adapt agricultural systems to climate change (sciences vie 2015).

The current permanent pasture definition indeed recognizes all types of permanent grasslands across European biogeographic regions better than the previous CAP, only associated to herbaceous grasslands. Thanks to the inclusion of the concepts of “self-seeded” (annual herbaceous species) and “grasses and other herbaceous forage are traditionally not predominant in grazing areas” ecological traits linked to species evolution strategy to survive shortcoming periods (summer) or disturbances (heavy rains, floodings..) are included, making the ecosystem more resilient to droughts, heavy rains, and avoiding erosion. However, when a member state decides to apply a pro-rata system (meaning that the surface of the woody component in permanent grassland is discounted for farm payments), this choice should apply for all permanent grassland parcels of the member state or region territory that has scattered ineligible features. This choice means that ineligible areas below 1000 m2 can be eligible, but unfortunately this is provided at parcel level (not per hectare), and therefore affecting different eligibility depending on the parcel size. Those farms with large parcels even including several hectares are only allowed to have 1000 m2 of woody vegetation. Another problem for agroforestry is the interpretation of the concept of “grazable trees” in permanent grassland. As indicates the EU (2015) “grazable" trees on permanent grassland, which are considered as part of the eligible area, should thus not be counted to assess whether the parcel is below or above the maximum tree density. However, the concept of grazable tree for the European Commission is summarized as those features "which can be grazed" and should be actually directly accessible to farm animals for grazing for their full area. Therefore the concept of grazable tree for the European Commission is linked to the fact that the animal can access to the food directly from the tree, making ineligible and therefore discounting those trees that are planted in the plot for providing fruit to animals when fruits fall down on the soil (i.e. Quercus ilex in the dehesa systems).

Regarding Pillar II, most of the regions of Europe has activated the promotion of new and/or the adequate management of hedgerows and isolated trees with at least one measure. It is important to highlight that the most popular rural development measure 10.1., the so called "agri-environment climate commitments" (AECM), so recognizing the role of the woody vegetation in Europe to improve environment and to reduce negative climate change impacts. The lack of recognition of agroforestry in the different measures of the CAP, even though the woody component is promoted somehow, reduces the impact of the agroforestry practices, as the connection between the crop or pasture and the tree for improving productivity and the selection of best species or varieties of both components to pursue a better productivity for an specific land is not pursued. The visibility of agroforestry should be clear, mostly for the accomplishment of decision 529/2013 (EU 2013c) regarding to the mitigation and adaptation to climate change. However, the specific agroforestry measure had a lower degree of implementation in most of the European Union regions. Some of the justifications to this fact, is (i) that to implement agroforestry practices under measure 8.2 may contribute to lose the direct payments of the specific plots (Mosquera-Losada et al. 2016c) which prevent farmers to use it due to the lack of an adequate link between Pillar I and Pillar II (ii) the lack of knowledge about how to better integrate the woody and agricultural component to increase productivity (iii) the lack of market for the use of the woody or agricultural component linked to an "agroforestry label" that will allow farmers to obtain benefits from the more sustainable use of the land and (iv) the lack of payment to farmers by ecosystem services or environment results.

Nowadays, the EU is aware of the huge existing divide between knowledge and implementation and created the European Innovation Partnership within the RDP as a horizontal approach. A huge amount of money has been allocated to different activities where farmers can discuss about sustainable practices and where agroforestry will play an important role. They are called operational groups. But also, the Commission supports the creation of transnational Focus Groups where researchers through a farmer driven structure discuss about specific subjects to be promoted within the operational groups. EURAF has been able to promote the agroforestry focus group with information, research future and problems that has to be solved to increase the extent and recognition of agroforestry in Europe (Agroforestry Focus Group 2017).

6.6 CONCLUSIONS

There is a clear recognition of the woody component within the CAP but not as agroforestry. The lack of this recognition makes that the design of best combinations between the woody component and the agricultural activity from the understory is not pursued as such, considering both spatial and temporal scales. We strongly recommend to identify agroforestry and agroforestry practices as such through the whole CAP, and if adequate agroforestry practice is implemented through a management plan, full Pillar I payment should be allowed on agricultural lands.

6.7 ACKNOWLEDGEMENTS

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7 DISCUSSION

Agroforestry is a sustainable land use currently recognized as such by many researchers that lead the inclusion agroforestry practices and systems by different EU strategies supporting measures within the previous and current CAPs. However, the adoption of agroforestry practices by farmers should be fostered understanding the farmers needs and supported by adequate business environment aligned with the CAP. Both aspects are analysed in this discussion.

7.1 Drivers and barriers perceived by farmers and experts

The mixed research method based on the qualitative and quantitative analysis were needed to clearly identify the main drivers and barriers perceived by farmers and experts. With regard to the qualitative analysis, aspects related to farmers driving forces and barriers identification to adopt agroforestry, how farmers should be motivated, how awareness and networking can be increased understanding their decision making process including subsidies or even consumers perception are discussed below and found as key points to increase the sustainability of land use systems.

Domínguez and Shannon (2011) state that land owners manage their lands with four axes in mind: economic expectations of the property, ethical reasons, how the land should look like and natural risks. The relationship between socio-psychological factors (e.g. cultural, demographic, economic, and social variables, including ancestors, peers and education) and how people make decisions in practicing agroforestry are inseparable, and must be considered if policy makers, extension agents, and agricultural educators hope to influence and improve landowners' agroforestry adoption and management (Saha et al. 2011).

The analysis derived from our data aimed at identifying the **driving forces** affecting 'why agroforestry is adopted or not'. The study shows that the major driving forces for implementing agroforestry are tradition in the family or the region, diversification of products that agroforestry provides, and learning from successful and inspiring experiences. Instead, the major drivers for implementing conventional farming were tradition, the lack of knowledge on agroforestry and management simplicity. Nevertheless, other factors affecting the decision were economic viability, existence of subsidies, time needed for dedication, soil quality, as well as age of the farmer and ownership of the land. Past research has shown that the land ownership is frequently a barrier to adoption of innovative practices (e.g. Knowler and Bradshaw 2007; García de Jalón et al. 2015). One of the reasons for not establishing agroforestry was that when planting trees, the land would be tied up for future uses. This finding appeared as the most important factor in the study performed by Flexen et al. (2014) in Ireland, showing that farmers, both agroforesters and non-agroforesters, would consider planting trees in their plots, if there were greater financial incentives, or if they own lands that were poor or unsuitable for farming (Flexen et al. 2014). A common attitude found amongst many farmers, both in our study and the previously mentioned study, was that farmers did not seem to plant trees in rich soils because of a lower farm net margin associated to the understory crop. They stated that they would only plant trees on marginal lands where farming was difficult or unprofitable.

Borremans et al. (2018) have also **identified** similar **barriers** for the implementation of agroforestry in Flanders (Belgium): (i) lack of useful tools for planning, designing and maintaining the systems, (ii). long-term productivity and adaptability of agroforestry, (iii) lack of knowledge (communication and education), and (iv) lack of support and shared vision among actors. In other popular polls outside Europe, e.g. in the case of Uganda, farmers were asked what was the biggest barrier for not practicing agroforestry. Results from 2770 responses reveal the following drawbacks (TrackFm 2017): lack of seedlings, tools and equipment (39%), lack of knowledge and skills (29%), it takes a long time before income can be generated (21%), growing crops like maize is more profitable (11%). Although these results relate to very different climatic and socio-economic conditions, it also highlights the need for technical advice and information. The lack of knowledge among landowners about agroforestry is considered to be a limiting factor so it needs to be improved through various types of education (FOREST EUROPE 2019).

Motivating farmers to manage more complex agroecosystems that are fundamentally different to their current simplified systems is challenging (Pannell 1999). Adoption of new agricultural innovations depends both on internal factors, such as knowledge, attitudes and perceptions, as well as on external factors, such the characteristics of the farm or the external business environment (Meijer et al. 2015). Understanding the internal factors is crucial to design projects that are locally relevant and more likely to be adopted, but both internal and external factors need to be considered simultaneously in order to understand how decisions are made (Meijer et al. 2015). Pannell (1999) suggests that a farmer considering a new system must (i) have the information about the system, (ii) be satisfied that it can be trialled, (iii) perceive that it is worth trialling, and (iv) and that it can support the objectives of the farm business, particularly profit. These conditions are not easily obtained in long-term systems such as agroforestry, in particular where the high initial investment costs are high and the full financial benefits may only be observed over a long period. Interestingly, many farmers interviewed in this study showed interest in the agroforestry practices and considered implementing it in their farms. This reflects openness and willingness but a lack of knowledge that the farmers have on alternative farming options; they would need to see examples that those practices are profitable and have many other advantages before deciding to invest in them. In order to attract farmer interest in investing lands with agroforestry systems, local demonstration plots where agroforestry practices are tested would be worthwhile. Some farmers would implement agroforestry practices if there were economic supporting measures, if they would perceive that the management was simple and if there would be approval from landowner in cases were the managed land is rented.

In order to encourage farmers to take up agroforestry, it is necessary to **raise awareness** among the farmers about the benefits of these practices, showing them examples of successful farms. Limited awareness of agroforestry among farmers and landowners was identified in the current study and by a number of other studies (McAdam et al. 1997; Doyle and Thomas 2000) and also highlighted by the AFINET project where technical, environment, economic and policy challenges were described by close to 1500 farmers. For example, in a study by Graves et al. (2009), only 33% of farmers correctly defined agroforestry as the integration of trees with crops or livestock systems showing the low share of awareness about this practice. Result that was also identified in the interviews performed in this thesis. These studies showed, however, that when farmers were shown agroforestry systems, their level of interest increased. Farmer-led projects have greater credibility in the eyes of other farmers (the peer-to-peer effect), thus one channel for raising awareness is to update the extension services with the latest developments and findings for further knowledge transfer. It was proven by Primmer and Karppinen (2010) that technical solutions suggested by technicians from extension services are incorporated by farm owners into their decision-making. Technicians are a relevant influencing agent for the owner to decide on the different management alternatives, in particular in cases with high uncertainty and complexity, e.g. price fluctuations and climate change (Schlüter and Koch 2009). Hauck et al. (2016) indicate that at the local level, technical journals were also an important source of information for farmers, advising them, for example, on the different agri-environmental schemes that were available, while linkages among farmers and all stakeholders for exchanging information are encouraged.

For these reasons, it would be beneficial to establish and/or **reinforce networks** among stakeholders in order to facilitate the flow of knowledge. Innovative farmers can find empirical solutions to their problems and experiment themselves with agroforestry practices. In this regard the Agroforestry Innovations Network - AFINET project has been a milestone covering to certain extent this knowledge gap, involving the different stakeholders (from researchers to practitioners, including policy makers and multipliers as extension services) across the different networks and activities in Europe. Also according to Borremans et al. (2018), the intention to start using agroforestry can only be increased if every obstacle is tackled: *'Research centres, governments, civil society organizations, (agricultural) companies and consumers must jointly commit to work on more research and development, other revenue and financing models, a sound legal framework and effective support measures, more knowledge sharing, broader support, and a shared vision'.*

The results of this PhD are in line with Saha et al. (2011) which indicate that farmers' **decision-making processes** were most influenced by factors such as ancestors and education, followed by peers, financial condition, and economic importance of the agroforestry land holding. When looking at the agroforestry farmers' drivers, also tradition and learning from other experiences appeared as main reasons for implementing agroforestry, together with diversification of products, which reduces the risk in production, another relevant aspect for the farmers. These main drivers contrast with those of farmers in other European regions not included in this study, e.g. Switzerland, where the primary motivations were habitat function, both for biodiversity conservation and shade for livestock (Sereke et al. 2016). Nevertheless, animal welfare was also mentioned as an important driver among the farmers interviewed. Animal health and biodiversity also played a role in the motivations of farmers in Estonia (Roellig et al. 2015). Most farmers believed their animals thrive better in a more "natural" environment, needing less medication. In a similar study in Ireland, most of the agroforestry farmers rated landscape improvement and environmental factors as very important factors, as well as provision of shelter for livestock (Flexen et al. 2014). The farmers in this PhD considered agroforestry as a good alternative for low productivity marginal lands. Improving the environment, aesthetic value and quality of life were further reasons for implementing agroforestry. Similarly, the motivation to conserve cultural landscapes through agroforestry was lower among non-adopters in Switzerland compared to adopters (Sereke et al. 2015). Other studies in France revealed that the difficulties in accessing the land and the need to reduce agricultural inputs through functional biodiversity and diversification motivated smaller farmers to combine annual plants and fruits with the aim to increase their plot performance on a multifunctional basis, increasing the number of such plots significantly in the last few years (EURAF 2015).

Existing **subsidies** also encouraged farmers to manage the land in certain ways. Some farmers in this study chose practices that receive subsidies, although many were not aware of existing subsidies for agroforestry, which, in any case, are rather limited and above all not targeted and leading, in some cases, to losses of land eligibility for Pillar I. Furthermore, other studies have shown that the availability of grants did appear to influence those who are already interested in planting trees on the fields but not those who are not (Lawrence et al. 2010). Roellig et al. (2015) identified in Estonia that the determining factor to encourage management or restoration of wood-pasture was financial support. On the other hand, most farmers had a clear passion for managing their land and were proud of maintaining their wood-pastures following local traditions. Regulations, on the contrary, might limit the use of different agroforestry components (e.g. hedges) and lands. The perceived behaviour revealed that farmers felt rather free to decide whether to practice agroforestry or not, but they believed that framework conditions do not allow adoption. Environmental regulation was not a motivation, then, for both adopters and non-adopters. Thus, although factors such as stewardship or farmer image might motivate a small number of farmers to use agroforestry systems, on a wider scale, voluntary adoption of agroforestry systems may need to be encouraged through subsidies, tax relief, or cross compliance, and compulsory adoption through government strategic plans, or penalties for non-adoption (Pannell 1999). Sereke et al. (2016) also justify subsidies for ecological production, and incentivize the local and indigenous agricultural products. Public support for land management is justified when such management provides public goods, e.g. environmental or social benefits such as rural vitality (EBCD 2012) as will be seen at the end of this discussion in the CAP section.

There is also a clear need for **raising awareness among the consumers,** as e.g. Galician farmers declared in AFINET, for them to give priority to agroforestry-derived products despite of higher prices, which in turn becomes an incentive for farmers. Duesberg et al. (2014) also recommended that, in addition to monetary incentives, policy tools such as image and information campaigns should be used. A broader knowledge about ecosystem services needs to be made available to farmers and to the society at large, to increase recognition of local ecological solutions (Sereke et al. 2016).

7.1.1 Quantitative analysis

To complement the qualitative analysis of the surveys to farmers, a quantitative approach with a questionnaire to experts was implemented to develop the Analytical Network Process (ANP) model. The quantitative analysis was based on the priorization provided by experts related to economic (agroforestry benefits and costs, business risk, labour costs, subsidies), environment and social benefits.

The ANP model, on the basis of the assumed weighting given to **benefits, costs**, **opportunities and risks**, gave the highest priority to High natural and cultural value agroforestry and a low overall priority to Do not implement agroforestry. Novel practices such as agroforestry with high value trees, and the selected practice of agroforestry for arable and livestock systems also received higher prioritisation than not implementing agroforestry. These results were reflected in the large extent of high nature and cultural value agroforestry in European countries in the Mediterranean zone. Such regions generally have the largest coverage of agroforestry in Europe, ranging from 10.9% of the utilized agricultural area in Italy to about 40.9% in Cyprus (den Herder et al. 2016).

The most important economic benefits were identified as lower business risk due to diversification and the production of higher quality crops and timber. This is consistent with the findings of Camilli et al. (2016; 2017), who reported that Italian farmers identified that the production of high quality products was one of the most important benefits of silvopastoral systems. It is also consistent with results on our interviews with farmers indicating that diversification of products, together with tradition and learning from others, was an important driver for the adoption of agroforestry (Rois-Díaz et al. 2018).

Increased **labour costs and competition between crops**, trees, and animals were identified as the most significant costs determining the uptake of agroforestry, mirroring the results of Sereke et al. (2015) and Camilli et al. (2016). The greatest opportunities were related to the availability **of subsidies and assistance from extension services**, and low market opportunities and lack of subsidies were seen as the greatest risks. Jalón et al. (2017) in a pan-European study and Camilli et al. (2016; 2017) in an Italian study also reported that the need for national demonstration sites and education programs to support the uptake of agroforestry.

The group of agroforestry experts perceived the most important **environmental** benefits as being a lower input of pesticides and fertilizers, improved water quality and improved flood regulation. By contrast the improvement of biodiversity, landscape aesthetics, soil conservation and animal welfare were given low priorities compared to those reported by Jalón et al. (2017).

7.1.2 Qualitative vs quantitative methodology challenges

In the qualitative interviews with farmers it was noted that some farmers who implemented agroforestry were unfamiliar with the term “agroforestry”. This lack of knowledge makes it difficult for a farmer to acknowledge the existence of the vast array of different criteria that are listed in the quantitative results from the ANP model. Those interviews reported on several variables behind uptake of agroforestry practices that were not included as criteria in the ANP model reported here: (i) age of the farmer (younger, rather than older, were more likely to implement agroforestry), (ii) income diversity (those with income from outside farming were more likely to implement), and (iii) tourism potential (farms with touristic potential were more likely to implement). A very similar approach to this study was taken by Camilli et al. (2017), where a comparable group of ‘agroforestry stakeholders’ (farmers, researchers, experts and policy makers) was asked on their perceptions on agroforestry in Italy, and where the feedback was generated through questionnaires administered in workshops, following a categorization of agroforestry systems that matches the decision alternatives in the ANP model of this study. Their study emphasized the importance of local supply chains for agroforestry products and management problems that might be caused by wild animals; issues that were not taken-up in this study. They also found that ‘stakeholders’ (mostly researchers), in comparison to farmers, have higher valued environmental aspects of agroforestry and downplayed the importance of management costs. However, on the overall range of descriptors of agroforestry, there was no statistically significant difference between the opinions of these two groups.

Potential limitations on the validity of the results of the ANP model include the bias of the respondents, the selection of the default farm type and alternatives, and respondent fatigue. The reported results were developed with reference to the specified farm description and description of management alternatives, and not directly to the agroforestry in the Mediterranean region. We acknowledge that there cannot be a single farm description that is truly representative of the region, and this is the greatest validity issue of this study. We have designed the management scenario in a participatory manner, bearing in mind all the diversity that exists in agroforestry practised from Spain in the West to Greece in the East. However, this management scenario entails compromises among different viewpoints, approximations and inherently deviations from actual situation. For example, in the EU Farm Accountancy Data Network average farm size in the sample for seven listed Mediterranean countries is 29 ha with 5.5% of forests, while the farm in our description is about seven times bigger but it has similar (7.5%) forest coverage. The ANP model was selected as multi-criteria decision model due to its ability to capture complexity. However, this strength also has some drawbacks. The experts involved may have understood the general idea, the relations among the elements and the pairwise comparison. However, they did not fully understood the calculation process and thus how priorities are generated. Many rounds of discussion and questionnaires may have caused respondent fatigue, especially for the questionnaire in which they had to judge 73 pairwise comparisons. The challenges caused by selection of ANP as the decision method is somewhat alleviated by the fact that respondents strongly agree that the results of the model 'are an adequate representation of a real-life situation'.

Although farmer and expert-focused approach studies continue to provide valuable insights, it is increasingly acknowledged that also the role of other actors should be included in the analysis, to find the relations between institutional, biophysical, structural and market considerations and their effect on farmers' choices (Borremans 2018). Our study selected the CAP, as it is the main policy driving the agricultural and forest sectors in Europe. Acknowledging the different benefits that agroforestry provide by using the quantitative and qualitative methods, it is clear that there is a need for funding to promote the business environment development as that provided by the CAP and policies to be discussed in the following section.

7.2 THE CAP AND POLICIES´ INFLUENCE IN THE IMPLEMENTATION OF AGROFORESTRY IN EUROPE

EU policies have not been promoting agroforestry in the old CAPs, but strong efforts have been developed in the recent ones. When analysing the CAP, challenges have been found that may limit the evaluation of agroforestry implementation in the CAP, that has been recognized as a sustainable land use system. This discussion also considers the main challenges associated to the implementation of Pillars I and II with regard to the farmers adoption of agroforestry including the AKIS system, and how the already approved EU and no EU strategies positively affect agroforestry in the CAP.

Understanding the impact of the CAP and specifically of agroforestry on European lands is **challenging** due to several reasons, such as (a) the capacity of countries to choose among different options within the CAP, (b) the variety of options regarding the implementation period, which is typically 7 years, (c) the different environmental and socioeconomic situation of the Member States, and (d) the varying number of EU countries implementing the CAP, which has increased in the last years, affording different degrees of adaptation to the policies as found by Santiago-Freijanes et al. (2018a; 2018b) and Mosquera-Losada et al. (2018b). Member States have to design their own CAP based on the EU CAP framework and choose among the different alternatives in order to adapt it to their own requirements and environments, which is a crucial aspect for agricultural sustainability. For example, the CAP framework of the period 2014-2020 was approved in mid-December 2013, which delayed the starting point to implement the CAP measures by member states around two years. The implementation of Pillar I of the 2014–2020 CAP started at the beginning of 2015, with an extension of the CAP 2007–2013 in 2014, while most RDPs set up their initial choices at the end of 2016, after which farmers could start to meet the requirements to receive support. Delays are even higher for the 2021-2027 CAP period, as the CAP has not been formally approved yet, but it will come soon and a prorogue of the previous one (2014-2020) has already been approved. From 2021 the new CAP framework will allow even more flexibility to the Member States by recognizing the need of accountability of the results of the implemented measures pursuing the SDGs and the current CAP aims with regard to economic, environment and social aspects as the Green Deal highlights. Furthermore, the CAP selection may be modified by Member States during the commitment period, and it is also reviewed and strongly modified at mid-term with important changes (e.g. OMNIBUS), making the evaluation of the global period extremely difficult.

The **European Commission recognized** in 2005 the social and environmental value of **agroforestry** systems (EU Reg. 1698/2005) and a specific measure (M222) supporting agroforestry was introduced in the 2007–2013 CAP. The measure (renamed into M8.2) was improved in the 2014–2020 programming period (EU Reg. 1305/2013) and it is expected that its uptake would increase in the next years.

One of the difficulties agroforestry practices present for promotion at the European scale has been the agreement on the definition. FAO (2015) defines agroforestry as '*a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals*'. In North America, AFTA (2016) defines agroforestry as '*an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock*', and USDA (2017) '*Agroforestry is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits*'. The inclusion of 'woody perennials' in the definition of agroforestry in the CAP (2014–2020) compared to the previous period (CAP 2007–2013), rather than exclusively 'trees', facilitates the sustainability and adaptation of farming systems to the existing different environments in the EU countries in the form of shrubs owing to their woody perennial nature, providing many of the same productive, environmental, and/or social benefits of trees (Mosquera-Losada et al. 2006; Rigueiro-Rodríguez et al. 2009). Moreover, tree definitions vary across countries, and trees can also be cultivated in shrub form while providing the same environmental and social benefits (Mosquera-Losada et al. 2016b), which makes difficult the distinction from trees and shrubs. The CAP definition of agroforestry applied in Measure 8.2 (2014-2020) is adequate, but the further inclusion of a two-layer concept could help to avoid confusion, for example in the case of using fruit trees when the crop is on the tree. Thus, the AGFORWARD project has proposed the following definition: '*the deliberate integration of woody vegetation (trees and/ or shrubs) as an upper storey on land with pasture (consumed by animals) or an agricultural crop in the lower storey. The woody species can be evenly or unevenly distributed or occur on the border of plots. The woody species can deliver forestry or agricultural products and other ecosystem services (i.e. provisioning, regulating or cultural)*' (Mosquera-Losada et al. 2017). Moreover, within the Pillar I regulation description, it is difficult to clearly identify the different types of agroforestry practices (silvopasture; silvoarable; hedgerows, windbreaks and riparian buffer strips; forest farming, and home gardens), which are typically referred to by local names mixing the practice (plot) and system (farm) concept (e.g. grazed orchards, wood pastures, dehesa, montado, parklands, hedges) but not clearly identified as agroforestry.

Den Herder et al. (2017) and Mosquera-Losada et al. (2016c) who considered exclusively the tree components (excluding shrubs) and woody components (trees and shrubs), respectively, are the first systematic studies to identify the extent and location of agroforestry use and practices in Europe. However due to the lack of data, unfortunately it is not possible to identify which of these agroforestry practices are linked to the CAP payments. The first step to improve the agroforestry policy in Europe is to identify the land where it is applied and how the policy modifies its implementation to create tailor-made agroforestry practice measures according to the needs of specific regions and the ecosystem services they should deliver. The extension of agroforestry practices should be based on a more flexible strategy pursuing the generation of products from woody vegetation while implementing sustainable practices using circular economy and bioeconomy approaches. The lack of recognition of the results or even the area where a measure is implemented it is cause of the failures of the previous CAP as highlighted by the Court of Auditors, indicating that the lack of monitoring reduces the acknowledgement of the economic, environmental and social benefits from the CAP payments

The promotion of the woody component in Europe can be appreciated in different sections of the CAP linked to Pillar I (Direct payments and Greening) and Pillar II (Rural Development Programs). However, agroforestry is not recognised as such in the CAP, with the exception of the Measure 8.2 of Pillar II 'Establishment of agroforestry systems'. The lack of recognition of agroforestry practices within the different sections of the CAP reduces the impact of CAP activities by overlooking the optimum combinations that would maximise the productivity of land where agroforestry could be promoted, considering both the spatial and temporal scales (Szedlak 2019).

Pillar I of the CAP involves the direct payments to arable, permanent crops and permanent pastures. When considering the eligibility for subsidies in arable land, in the CAP 2014-2020 no more than 10% of the arable land is allowed to have an already existing woody component, a number that has been increased from the CAP 2007–2013, where only a 5% was allowed. However, these rules are still not enough to ensure the productivity and resilience of European arable systems since the tree density does not correlate with the concept of 'mature tree' and most Member States take this density as a limit for any new tree plantation in the European Union. Crown diameters of over 4 m can be considered in most cases mature trees, and trees with diameters smaller than 4 m are not protected even if they are essential to ensure the long term sustainability of isolated trees. The 50 trees ha^{-1} limit given for arable land in the previous CAP (2007–2013) has been increased to 100 in the current CAP (2014–2020). The adoption of any tree density as a limitation to pay farmers within the CAP framework have caused the destruction of trees, mostly in small plots of farms. This affected both those areas already land receiving Pillar I payments and those lands that farmers are intending to include for future CAP support. Hedgerows larger than 2 m are not generally considered eligible by the EU, even if the hedgerows are protected, which makes farmers associate them with a reduction of the CAP support, despite the ecosystem services they deliver, and farmers may reduce their size if not destroy them all together. By contrast, alley cropping or silvoarable practices linked to permanent crops (including fruit trees and short rotation coppices) are allowed and fully eligible in the current CAP, but they are not promoted or even specifically mentioned.

Another aspect that undermines the use of woody vegetation in the CAP is that the CAP does not consider the form and the function of the woody vegetation; instead the assumption is that the reduction in agricultural activity is solely dependent on the tree density. The tree density criterion has at least three main drawbacks: (i) the limiting factor for radiation to reach the understory is not only associated to the tree density but the tree coverage, which can nowadays be easily measured using satellite images but that is not considered by the CAP, (ii) the general assumption that the reduction of radiation necessarily reduces the understory production, while in practice, some crops adapt and are more efficient under shade conditions, even increasing their productivity, and (iii) the lack of a link between the tree density and the temporal dimension. In some areas, such as the dehesa in Spain, the presence of trees in a plot extends the growing season during droughts and extreme heat, which is important for the adaptation of agricultural systems to climate change (Sciences Vie 2015).

The current permanent pasture definition recognises all types of permanent grasslands across European biogeographic regions better than the previous CAP, in which it was only associated with herbaceous grasslands. However, when a Member State decides to apply a pro-rata system (meaning that the surface of the woody component in permanent grassland is discounted for farm payments), it is applied to all permanent grassland parcels of the Member State or region territory with scattered ineligible features. This choice means that previously ineligible areas smaller than 1000 m^2 are now eligible; unfortunately, this is applied at the parcel level (not per hectare) and therefore the eligibility depends on the parcel size. Farms with large parcels, even those extending several hectares, are only allowed to have 1000 m^2 of woody vegetation. The woody vegetation of permanent pasture has been protected to some extent in those countries where Established Local Practice (ELP) are applied. However, some countries have decided not to make eligible pastures dominated by woody vegetation by not using the ELP option, limiting the positive effect that woody vegetation could have for animal feeding during the drought period of the summer in Southern countries. Another problem for agroforestry is the interpretation of the concept of 'grazable trees' in permanent grassland. As the EU (2015) indicates, 'grazable trees' on permanent grasslands, which are considered part of the eligible area, should not be accounted for when assessing whether the parcel is below or above the maximum tree density. However, the concept of 'grazable trees' for the European Commission refers to those features 'that can be grazed' and should be actually directly accessible to farm animals for grazing of their full area. This implies that the animals must access the food directly from the trees, rendering ineligible and therefore not counting those trees that have been planted in a plot to provide fruit to animals during the fruit drop season (i.e. *Quercus ilex* in dehesa systems). Fortunately, this changed with the OMNIBUS directive.

Regarding **Pillar II**, most regions of Europe have activated the promotion of new and/or adequate management of hedgerows and isolated trees with the measure Measure 10.1 'Payment for Agri-Environment-Climate Commitments AECMs' recognising the role of woody vegetation in Europe for environmental improvement and the reduction of negative climate change impacts. However, the specific agroforestry measure (Measure 8.2) has had a low degree of implementation in most European Union regions. Some of the reasons are: (i) the implementation of agroforestry practices under Measure 8.2 may contribute to the loss of direct payments for specific plots (Mosquera-Losada et al. 2016a), thus farmers might avoid applying them due to the lack of an adequate link between Pillar I and Pillar II; (ii) the lack of knowledge on how to better integrate the woody and agricultural components to increase productivity; (iii) the lack of a market for the woody or agricultural components perhaps linked to an 'agroforestry label', that would allow farmers to obtain benefits from a more sustainable use of the land; and (iv) the lack of payment to farmers for ecosystem services or environmental results.

Other measures within Pillar II that can be used for promoting agroforestry in forest land in a more indirect way, e.g. through education are measure 1.2 with the establishment of demo sites or measures 2.1 and 2.3 by fostering farmers and advisors knowledge, or as fire prevention through measure 8.3, measure 12.1 to improve Natura 2000 areas, measure 15.2 to preserve forest genetic resources, or measure 8.6 on technologies related to processing, mobilizing and marketing forest products and value-chain (Rigueiro-Rodríguetz et al. 2021). Also measure 15.1 for forest environmental and climate commitments could apply as payment for ecosystem services. In any case, it is the decision of the Member States and the regions to activate or not such measures.

Lack of consistency between Pillars have been recognized as one of the main drawbacks to adopt agroforestry in Europe by farmers. Eligibility was always proposed by the EU and it was a key aspect in the previous (2007-2013) and current CAP (2014-2020) and usually penalizes those areas where woody perennials (trees or shrubs) were present. The forthcoming CAP (2021) aims at providing Member States with more responsibility on the way that CAP is implemented including eligibility, but makes compulsory to provide results which will be linked to results-based payments (Mosquera-Losada et al. 2019c). CAP Strategic Plans have just been approved in June 2021, but the specific deployment of them with regard to agroforestry are still unknown.

The EU is aware of the huge existing **divide between knowledge and implementation**, and has thus created European Innovation Partnerships as a new horizontal approach within the RDPs of the Pillar II. The EIP-AGRI acknowledges what the actors of the AFINET RAINs have highlighted, which is important for extending agroforestry, as suggested Mosquera-Losada et al. (2017) in the AGFORWARD policy recommendations (Villada et al 2018). Budget has been allocated to Operational Groups who can undertake different activities where farmers can discuss and develop sustainable practices such as agroforestry. Moreover, the Commission also supports the creation of transnational Focus Groups, where researchers and practitioners are able to discuss specific subjects of interest to the Operational Groups. During 2017, the European Agroforestry Federation supported the Agroforestry Focus Group by providing information, future research directions, and identifying problems that need to be solved to increase the extent and recognition of agroforestry in Europe (Agroforestry Focus Group 2017).

Not only the CAP will have an impact on the implementation of agroforestry, several **other policies** have been identified in Santiago-Freijanes et al. (2021). Positive effects of trees and shrubs to adapt agricultural landscapes to climate change, mitigating some of its negative effects or intensity, had not been sufficiently acknowledged and promoted among the public and policy makers, while agroforestry can effectively contribute to a number of high-level environmental and societal goals (FOREST EUROPE 2019). Nevertheless, recent developments can be observed as natural capital is more prominently acknowledged by governments and institutions, but also by the private sector. In 2021, United Nations (UN 2021) is launching a new instrument to measure the economic growth and the human wellbeing of the countries, including nature capital. This will allow the governments to integrate the environment in their growth indicators. The new environmental accounting will be based on the European statistics and will be used for the implementation of the European Green Deal. This new instrument could increase the visibility of the agroforestry contribution to the mitigation and adaptation of climate change and the ODS in general. Furthermore, the new Terra Carta provides a roadmap to 2030 for businesses to move towards an ambitious and sustainable future, that will harness the power of Nature combined with the transformative power, innovation and resources of the private sector.

The 10-point Action Plan for a Circular Bioeconomy of Wellbeing (Palahí et al. 2020) highlights within the transformative action point ‘Rethink land, food and health systems holistically’, that agroforestry systems could enable agriculture to become a net carbon sink, rolling climate change backwards profitably, as it revitalises rural communities and enhances human health, and sets as example local Payments for Ecosystem Services (PES) contracts that have been signed to contribute to forest cover restoration and halting deforestation by promoting agroforestry. ‘Forests, landscapes and agroforestry can catalyze this vital transformation as they are our main terrestrial natural capital supporting wealth creation in rural and urban areas’ (Palahi in CIFOR 2021). Farmers face uncertainty about profitability and long return on the investment through wood production, while they are not compensated for the environmental services that the trees supply in the meantime. There is a need for creating market mechanisms that enable farmers to valorize their efforts for the environment, landscape and biodiversity, through, e.g. PES, carbon trading or an agroforestry label that creates added value (Borremans et al. 2018).

The European Bioeconomy Strategy (2018) answers to the challenges that Europe and the world are facing: increasing populations that must be fed, depletion of natural resources, impacts of environmental pressures and climate change. All items made from fossil fuels can also be made out of renewable materials, thus agroforestry can support providing many of the resources needed in a sustainable production (Rois et al. 2019b). While the industry needs to adapt to the bioeconomy, demanding sustainably produced raw and circular materials, the EU Commission needs to understand the realities of the farmers to devise real supportive policies.

8 CONCLUSIONS

From the analyses performed in this doctoral dissertation we can conclude the following:

1. While the major drivers for implementing conventional farming instead of agroforestry were tradition, the lack of knowledge on agroforestry and management simplicity, the major driving forces for implementing agroforestry were tradition in the family or the region, diversification of products that agroforestry provides, and knowledge acquisition through learning from successful peers' experiences. The diversification of products is linked to increasing the resilience of the farms to market or climate threats.
2. Farmers in general did not plant trees in rich soils because of a lower agricultural farm net margin, while in some countries planting trees would limit the use of the land in the future. Agroforestry was perceived as a good alternative for low productivity marginal lands.
3. Factors affecting the decision on whether to implement agroforestry or not were also: economic viability, existence of subsidies, time needed for dedication, soil quality, as well as the age of the farmer and ownership of the land. Animal welfare together with improving the environment, aesthetic value and quality of life were further reasons for implementing agroforestry.
4. An appropriate agroforestry definition was only provided by few farmers indicating a low share of knowledge about this practice. After explaining the farmers, their interest increased and declared to be willing to implement agroforestry in their farms. They demand demonstration plots to show the benefits of these practices, playing the extension services a crucial role. It would also be beneficial to establish or reinforce networks among stakeholders in order to facilitate the flow of knowledge.
5. Some farmers would implement agroforestry practices if there were economic supporting measures. However, many farmers declared not being aware of existing subsidies for agroforestry, which, in any case, are rather limited in the Pillar II of the CAP and might compromise the eligibility of the land for CAP Pillar I subsidies.
6. Experts identified the lower business risk due to diversification and the production of higher quality crops and timber as the most important economic benefits of implementing agroforestry. Increased labour costs and competition among crops, trees, and animals were identified by the experts as the most significant costs determining the uptake of agroforestry. As for farmers, the experts found that the greatest opportunities are related to the availability of subsidies and assistance from extension services, while low market opportunities and lack of subsidies were seen as the greatest risks. The most important environmental benefits identified by the experts were the lower input of pesticides and fertilizers, improved water quality and improved flood regulation. By contrast, the improvement of biodiversity, landscape aesthetics, soil conservation and animal welfare were given low priorities.
7. The promotion of the woody component in Europe is reflected in different sections of the CAP linked to Pillar I (direct payments and greening) and Pillar II (rural development programs). However, agroforestry is not recognised as such in the CAP, with the exception of the Measure 8.2 of Pillar II 'Establishment of agroforestry systems'.

8 The main drawbacks identified for the arable lands in the CAP were: (a) coverage of woody vegetation is limited to 10% in the CAP 2014-2020, although previously was only 5%, (b) density of trees is limited to 100 trees ha^{-1}, while previously was only 50 trees ha^{-1}, (c) hedgerows larger than 2 m are not generally considered eligible, even if they are protected. These limitations have caused the destruction of trees and shrubs in farm plots in order to become eligible for Pillar I payments across the whole EU.

9 By contrast, alley cropping or silvoarable practices linked to permanent crops (including fruit trees and short rotation coppices) are fully eligible in the current CAP, but they are not promoted or even specifically mentioned to foster agroforestry.

10 Concerning permanent grasslands, the woody vegetation of permanent pasture has been protected to some extent where Established Local Practices (ELP) are applied by Regional or National Development Programmes. Furthermore, 'grazable trees' in the CAP initially referred to those that can be directly grazed by the animals, rendering ineligible those trees that that provide fruit to animals during the fruit drop season. Nevertheless, this changed with the OMNIBUS directive during the CAP implementation period.

11 The Measure 8.2 of Pillar II 'Establishment of agroforestry systems', which applies in forest land, has had an overall limited uptake across Europe due to the competition with Measure 8.1 'Afforestation and creation of woodland', by which only afforestation or reforestation activities are requested and farmers get funding for longer than 15 years, independently if they implement AF or not. However, the agroforestry measure 8.2 only provides funds for a shorter period of time.

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Farmers' reasoning behind the uptake of agroforestry practices: evidence from multiple case-studies across Europe

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Abstract Potential benefits and costs of agroforestry practices have been analysed by experts, but few studies have captured farmers' perspectives on why agroforestry might be adopted on a European scale. This study provides answers to this question, through an analysis of 183 farmer interviews in 14 case study systems in eight European countries. The study systems included high natural and cultural value agroforestry systems, silvoarable systems, high value tree systems, and silvopasture systems, as well as systems where no agroforestry practices were occurring. A mixed method approach combining quantitative and qualitative approaches was taken throughout the interviews. Narrative thematic data analysis was performed. Data collection proceeded until no new themes emerged. Within a given case study, i.e. the different systems in different European regions, this sampling was performed both for farmers who practice agroforestry and farmers who did not. Results point to a great diversity of

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agroforestry practices, although many of the farmers are not aware of the term or concept of agroforestry, despite implementing the practice in their own farms. While only a few farmers mentioned eligibility for direct payments in the CAP as the main reason to remove trees from their land, to avoid the reduction of the funded area, the tradition in the family or the region, learning from others, and increasing the diversification of products play the most important role in adopting or not agroforestry systems.

Keywords Interviews · Narrative thematic analysis · Driving forces · Farming

Introduction

Europe is characterized by a predominantly rural landscape (Eurostat 2016). In 2013, there were 10.8 million farms across the EU28, working 174.4 million hectares of land (Utilised Agricultural Area or UAA), i.e. 40% of the total land area of the EU28, while the forested area of the EU is slowly increasing and covers a slightly greater proportion of the land than is used for agriculture, 42% (Eurostat 2016). According to den Herder et al. (2017) the total area under agroforestry in the EU27 is about 15.4 million ha which is equivalent to about 3.6% of the territorial area or 8.8% of the UAA. The same authors found that Mediterranean countries such as Spain, France, Italy, Greece and Portugal have the largest absolute proportion of agroforestry.

Over the last few decades, there has been a clear pattern of rural land abandonment and migration of people from rural to urban areas (Renwick et al. 2013; Pointereau 2008; Keenleyside et al. 2010). The motivation for this movement varies between regions but a common factor is related to agricultural profitability (Breustedt and Glauben 2007). The number of farmers in Europe is declining and their average age is going up (EC 2015). Maintaining agricultural activities, particularly in low-productive areas, becomes difficult and agricultural land is abandoned, having consequences beyond the local economy (García-Ruiz and Lana-Renault 2011; Moreira and Russo 2007). To stop abandonment of rural areas, public and private support needs to be enhanced (Olper et al. 2014). Agroforestry is one of the activities that could help to stimulate rural areas by providing additional employment and financial revenue in a sustainable way (Mercer et al. 2014; Valdivia et al. 2009; Rancane et al. 2014).

However, adoption of agroforestry systems has been constrained by various environmental and socio-economic factors. To promote its uptake, it is important to understand how farmers perceive agroforestry systems and identify what the opportunities and constraints might be from their perspectives. Much research regarding farmers' perceptions of agroforestry has been undertaken in tropical countries, where the focus is on understanding local practice, opportunities for improvement, and why interventions succeed or fail (Graves et al. 2004; Barrance et al. 2003; Franzel 1999, Fischler and Wortmann 1999; Dreschel and Rech 1998). However, much less of such research exists in a European context or in the context of highly mechanised agriculture (Graves et al. 2009). What does exist has examined the use of agroforestry practices within a broad farming systems context, for example as riparian strips (Ducros and Watson 2002), hedgerows (Morris et al. 2002), windbreaks (Matthews et al. 1993), and as silvopastoral systems (McAdam et al. 1997). Such techniques have been accepted by farmers for a number of reasons, for example, because they have an obvious functional benefit (shelter for crops or animals), are existing features of the landscape (hedgerows), or because there may be limited options for the using the land for other activities (riparian strips). In a pan-European survey of farmer perceptions of silvoarable systems in England, the Netherlands, Germany, France, Spain, Italy, and Greece undertaken for the Silvoarable Agroforestry for Europe (2001–2005) project, Graves et al. (2008) reported that 86% of interviewed farmers were willing to use silvoarable systems, but only under particular conditions, the most important of which was confidence in their profitability. In the countries where the survey took place, 16% of farmers did not think there were any benefits at all from silvoarable systems; but 30, 16, 11, and 7% of farmers thought there could be economic, diversification, environmental, and landscape benefits respectively (Graves et al. 2008).

Regarding the adoption of new practices, particularly long-term systems, where a new system differs substantially from existing systems, Pannell (1999) has suggested four conditions necessary for adoption: firstly, the farmer must perceive that an alternative system exists, secondly, perceive that it can be trialled, thirdly perceive that it is worth trialling and fourthly perceive that it meets required objectives, particularly profit. These conditions are not easily obtained and in developed countries, three major difficulties inhibit the adoption of new technologies; firstly, developing an alternative system that is financially beneficial, secondly, assessing whether it is more profitable than the current system and thirdly, overcoming the farmer's uncertainty regarding the system.

The intention of the interviews was to perform a thematic analysis to address the research question: 'why is agroforestry accepted or not'? The aim was to assess which factors act for and against the adoption of agroforestry systems by European farmers, understand the knowledge the farmers have on these systems and identify the reasons why they might have removed trees from their land. The study was framed within the European project 'Agroforestry that Will Advance Rural Development' (AGFORWARD) that aims to promote agroforestry practices in Europe that will advance rural development i.e. improved competitiveness, and social and environmental enhancement.

Materials and methods

Materials

An inductive approach was chosen, as it is usually used in this kind of narrative analysis because it synthesizes data while facilitating a broader understanding of the data collected.

The selection of the respondents was as random as possible after stratification into two groups: farmers practicing conventional agriculture (A), and farmers practicing agroforestry (AF); and under four different categories used in the AGFORWARD project, i.e. (i) High Nature and Cultural Value farms, (ii) high value trees, (iii) arable and (iv) livestock agroforestry (Burgess et al. 2015; den Herder et al. 2017). High Nature and Cultural Value agroforestry includes traditional systems such as the *dehesas* and *montados* in Spain and Portugal, which clearly belong to the high nature value farming systems in Europe (Moreno et al. 2016; Bugalho et al. 2011). In high value tree agroforestry the main objective is growing permanent woody crops such as fruit orchards, olive groves, and nut trees. In arable and livestock agroforestry, either crop or livestock production is integrated with trees. It should be noted that these categories are not mutually exclusive. For instance high value tree agroforestry can be practiced as either an arable or a livestock system. Nevertheless, we prefer to recognise these four categories as separate systems as the farmer's objectives and the main components of the system (traditional systems delivering cultural and ecosystem services, trees producing fruits or high value wood, crop or livestock production) are different. The farmers not implementing agroforestry were selected as having a similar production sector in the same region. The farmers were recruited from lists available in agricultural extension services and where lists would not suffice, contacts from the interviewers,. Interviews were performed either face-to-face or by telephone; in both situations they were asked for permission to record it.

A total of 183 interviews were performed in eight European countries: Spain, Italy, Greece, Portugal, France, Germany, UK and Hungary. The final number of interviews performed by sub-system and region is shown in Table 1. In the case of the UK it was very difficult to get conventional farmers engaged, thus no interviews were performed with conventional farmers. In the case of Italy and Hungary, no interviews were performed with conventional farmers because of the fact that all sheep breeders raise the sheep in agroforestry systems.

Socio-economic overview of the farmers

Several practices have been described by the agroforestry farmers interviewed; these do not cover all existing practices in Europe, but only the ones present in this study. These are High Nature and Culture Value, hedgerows, grasslands with scattered trees, montado, dehesa and other wooded pastures and grazing in dense forest. In some cases of silvopasture systems, the grazing takes place only for a few months in the year, while in many cases they practice holistic grazing all year round.

A large proportion of the farmers (86%) were male. Over half of the farmers (62%) considered

Table 1 Distribution of the sampling for performing the interviews to farmers across Europe

Agroforestry system	Region	Country	AF interviews	A interviews
High nature and cultural value (HNCV)	Central Greece/Central Macedonia/Chania/Western Greece (EL1)	Greece	8	8
	Santarém (PT)	Portugal	8	8
	Extremadura (ES1)	Spain	9	8
	Brandenburg (DE)	Germany	8	8
High value trees (HNV)	England (UK1)	United Kingdom	5	0
	Northern Ireland (UK2)	United Kingdom	1	10
	Galicia (ES2)	Spain	4	7
Arable agroforestry (AA)	England (UK3)	United Kingdom	9	4
	Central Greece/Western Macedonia (EL2)	Greece	8	8
	Brandenburg (DE)	Germany	8	8
	Midi-Pyrenees (FR)	France	8	9
Livestock agroforestry (LA)	Galicia (ES2)	Spain	9	7
	Hills of Transdanubia/Great Plain (HU)	Hungary	7	0
	Toscana (IT)	Italy	6	0
			98	85
TOTAL			183	

AF agroforestry, *A* conventional agriculture

themselves as farmers or farm managers, 7% livestock breeders, 6% farmers with a second occupation, e.g. researcher, teacher, technical advisor, consultant, business man, forest company, 5% fruit growers and the remaining 20% have other occupations as main source of income, e.g. civil servant, carpenter, consultant, metal worker, shepherd, teacher, veterinary.

With regards the level of education, half (53%) of the farmers hold university degrees, mainly in the agricultural sciences. A 19% hold a high school degree and another 17% had only elementary studies. A small sample (3%) was educated in a vocational school, while a similar number (3%) did not have any formal level of education. A few farmers were reluctant to share their level of education (5%).

On average, farmers were 48 years old, while the age range was 23–80. The number of descendants varied between none and 7, with an average of 1.5 children.

There was a wide variation in size between the farms, ranging from very small (0.1 ha) to very large (11,000 ha). The largest farms corresponded mainly to the 'montado' and 'dehesa' systems in Portugal and Spain, thus the standard deviation (STDEV) is rather high. There was also considerable difference in the subsidies claims, from farmers that do not apply for any subsidy to those that get subsidies for the whole farm area (Table 2). The parameter 'CAP 2007–2013 vs. total size' refers to the comparison of the size of the farm under CAP subsidies to the actual size of the farm, thus we can observe that most of the farmers claim the entire farm under the CAP (MODE = 0), while the average says that not all the hectares are claimed (MEAN = − 128.34). The parameter 'CAP 2014–2020 vs. CAP 2007–2013' indicates that most of the farmers claimed or are planning to claim a similar area in both periods (MODE = 0), while the trend is to increase slightly the area under subsidies (MEAN = 3.47).

Table 2 Size of the farms of the interviewed farmers and area eligible claimed under the CAP 2007–2013 and CAP 2014–2020

Area (ha)	MIN	MEAN	MAX	STDEV	MODE
Size of the farm	0.1	363.10	11,000	993.84	20
Size eligible CAP 2007–2013	0	242.24	6612	674.30	0
Size eligible CAP 2014–2020	0	263.34	6612	697.14	0
CAP 2007–2013 vs total size	− 4388	− 128.34	0	448.26	0
CAP 2014–2020 vs CAP 2007–2013	− 70	3.47	320	33.39	0

MEAN average, *MIN* minimum value, *MAX* maximum value, *STDEV* dispersion of a set of data values, *MODE* most frequently occurring value in the range of the data

Methods

Qualitative interviews were made with farmers implementing and not implementing agroforestry, grouped by different sub-systems across Europe, and were analysed following the inductive research methodology of thematic analysis.

This research tried to enhance generalizability by conducting a thorough job of describing the research context and the assumptions that were central to the research, however the problem remains with transferability, because the researcher who will in the future try to "transfer" the results to a different context will be responsible for making a judgment of how appropriate the transfer is (Fereday and Muir-Cochrane 2006). Transferability is considered as a preference in a research in order to assure external validity and generalizability. This research has enabled to some extent allowance of transferability by providing sufficient detail of the context of the fieldwork for a reader to be able to decide whether the prevailing environment is similar to another situation with which he or she is familiar and whether the findings can justifiably be applied to the other setting (Shenton 2004). External validity is concerned with the extent to which the findings of one study can be applied to other situations. In Firestone (1993) there is a good presentation of a similar argument, it suggest that it is the responsibility of the investigator to ensure that sufficient contextual information about the fieldwork sites is provided to enable the reader to make such a transfer. In this context the study provides enough guidance and explanation for the readers to be able to try and replicate the findings in other settings.

There were two types of questions in the interviews: 'simple', or closed format questions, and 'complex' or open format questions. The 'complex' questions were the ones through which the thematic narrative was sought, given they were appropriate enough, i.e. having substantial information, for qualitative analysis. Table 3 shows the protocol of the interviews performed.

Saturation, i.e. answers starting to repeat between farmers, was observed on average after 8 interviews. In the cases where fewer interviews were performed, the causes varied from difficulties in getting the farmers involved, or that it was not possible to identify conventional farms in those regions, e.g. sheep were farmed exclusively in agroforestry land in Italy and Hungary.

An inductive approach on thematic narrative analysis was used for exploring the agroforestry application phenomenon, adapted from Saldana (2009). Thematic narrative analysis is useful because it synthesizes data while recognizing the contributions and facilitating broader understanding of data collected (Fereday and Muir-Cochrane 2006). Thematic analysis is one of the most common forms of analysis in qualitative research. It emphasizes pinpointing, examining, and recording patterns (or "themes") within data (Guest 2012). Themes were seen as patterns across the data sets that were important in describing the agroforestry application practices and were associated with our research question. The themes become the categories that derived from the analysis. Thematic analysis was performed through the process of coding in several phases to create emerging and meaningful patterns. The process of developing the themes divided into A and AF sections was the following: (i) Stage 1:

Table 3 Protocol of the interviews to the farmers across Europe

Group of questions	Question
1. Farm characteristics	What do you understand by agroforestry?
	How did you obtain the farm?
	What is the size of your farm?
	What is the size of your property eligible for CAP?
	What kind of land do you have on your farm? How much?
	Did you declare some landscape features in the previous CAP?
	Have you removed some trees from your land in order to be eligible for subsidies?
	Are you planning to apply any greening measures in the CAP 2014–2020?
	Do you have a diversified production system? Do you think diversifying your production is useful?
	Do you have permanent grasslands? Are you interested in preserving them or changing them into another type of land? Do they have trees on the grasslands? Is there any associated problem?
	Do you have any agroforestry practice on your farm?
2. Agroforestry farm characteristics	Do you describe the management of your agroforestry systems as "intensive" or "extensive"?
	Would you categorise any agroforestry systems as of either high nature and cultural value, as involving fruit or high value trees, or involving arable or livestock systems?
	When did you start agroforestry, and what is the size of the agroforestry area?
	Why did you start using agroforestry?
	Did you have any major problems implementing agroforestry, and if yes which kind of problems?
3. No agroforestry	Why did you choose to apply only conventional farming instead of combining it with agroforestry?
4. Perceptions on agroforestry	Please state several positive and several negative aspects of agroforestry, with respect to its
	Production aspects
	Environmental aspects
	Social aspects
5. Providing new information	
6. New perceptions on agroforestry	After the new information given, please state several positive and several negative aspects of agroforestry, with respect to its
	Production aspects
	Environmental aspects
	Social aspects
	Would you now consider applying agroforestry practices in your farm?
	Do you think that a specific label for this more extensive production is needed?
7. Personal information	Please state your:
	Age
	Gender
	Occupation
	Education
	Number of descendants
8. Concluding questions	Would you like to have feedback of the research?
	Do you have some questions or comments?

Developing the code manual, (ii) Stage 2: Finding the connections between the codes, (iii) Stage 3: Summarizing data and identifying initial themes, (iv) Stage 4: Additional coding, (v) Stage 5: Connecting the codes and legitimizing themes, (vi) Stage 6:

Summarizing final themes and supporting them with quotations.

Thematic narrative analysis is a categorizing strategy for qualitative data, by doing data review, making notes and sorting it into categories, adapted from Creswell (2009). As a data analytic strategy, it helped to move the analysis from a broad reading of the data towards discovering patterns and developing themes (Creswell 2009; Merriam 2009). This kind of interpretative analysis attempts to describe, explain and understand the lived experiences of a group of people (Charmaz 1995). The raw data in the beginning of the analysis were given conceptual labels. Each code or concept was constantly compared to all other codes to identify similarities, differences and general patterns. Themes gradually emerge and move from a low level of abstraction to become major themes, until the point they become concepts directly related to the research question (e.g. a category of reasons why is AF implemented or not, or barrier which stops the adoption of AF in a certain region). The analysis starts by the researcher listening to the recording, and marking a time frame with words that describe that period of conversation. Several elements were used simultaneously to describe a segment of the interview. This was the initial coding phase. Afterwards, the entire interview was coded in such a manner that the researcher tried to systematize the codes by producing 'categories' of codes. Each 'category' contained its explanation, called a 'memo'. This memo contained all the relevant information to describe the code. If applicable, then the researcher tried to systematize them further in even more abstract and general groups of codes. The groups of codes found did not necessarily relate to the questions within the interview protocol. They were also related to any possible themes that bring about some understanding of the research question (i.e. why is AF accepted or not). Some of them had multiple levels of codes. This number of codes, memos and categories was kept manageable, so the researcher can still be able to find logic between their connections and find the most important emerging themes.

The process of developing the themes divided in A (Agroforestry) and AF (Conventional agriculture) sections consist of the following phases:

Stage 1: Developing the code manual
Stage 2: Finding the connections between the codes
Stage 3: Summarizing data and identifying initial themes
Stage 4: Additional coding
Stage 5: Connecting the codes and legitimizing themes
Stage 6: Summarizing final themes and supporting them with quotations

Three types of coding were performed on the data: 'initial', 'in-vivo' and 'pattern' coding:

I. 'Initial coding' refers only to condensing the data to more manageable (shorter) units that can be listed and categorized more easily in the later phases. The essence of the ideas was captured with a few words, and the transcribed text was condensed. This is quite purely inductive thematic research, meaning there were no hypotheses to test, but just iteration of the data towards new findings. In other words, as a rule there were no predefined categories.
II. 'In-vivo coding' or direct quotations for either particularly typical or unique aspects (definitions, causalities, etc.) were written down for each question. This was done during the other coding rounds.
III. 'Pattern coding' is an iterative process of categorizing the initial codes (i.e. the shortened text fragments) into relevant meta-codes and sub-codes. It identifies patterns from the condensed data, leading to a system of sub-codes to develop a set of main themes and related sub-themes, in which the researcher inserts the finding into it. Judgement by the researchers who analysed the data was applied and additional categorizations were performed where needed. Some of them were overlapping but, in all cases, they were categorized as meta-codes in general themes and sub-codes in sub-headlines. Categorization of the variables was performed at the end. Some of the 'answers' to questions were found under other topics that are not covered by the interview protocol as they were asked in questions in subsequent interviews. The definitions of codes and of their memos evolved as they progressed through the analysis.

Relevant 'in vivo quotations' are shown between quotation marks and in italic font, followed by the country and partner recording it. When elaborating emerging themes on the questions, the acronyms used in Table 1 are used, i.e. country, partner, type of farming practice (A/AF) and type of system.

Given that the combination of qualitative and quantitative methods is encouraged (Suddaby 2006), in the interview protocol, there were also questions related to the socio-economic situation of the farmers, which were analyzed quantitatively. Though the sample and qualitative analysis of the answers has no statistical significance to allow general conclusions to be drawn, it was used to support the findings from the interviews. The open responses were analyzed qualitatively with the support of the MAXQDA 11.0 software (MAXQDA 2016). The software assists in organizing and grouping the above mentioned coding.

Thematic analysis was used for example in a study conducted by (Thierry and Snipes 2015) and tries to explain the reasoning behind delayed treatment for injuries in farmworkers by interviewing them and then using open-ended injury narratives coding for attitudes related to injury timing and delay. Narratives arriving from the data were then compared against demographic survey attributes in order to assess contextual information and patterns linked to treatment timing. Another example is an interview study of forest consultants employed by the Swedish Forest agency (Lidskog and Löfmarck 2016), where a contextualized thematic analysis was conducted in order to obtain knowledge of forest consultants and how they perceive and handle challenges in their advisory activities regarding the implications of bringing about strategies for forest consultants and forest policy. They used thematic analysis in order to find patterns (by using open, tentative, focused and selective coding) of broad challenges experienced by the consultants in their advisory practice. As a challenge in this study, they experienced transferability of their valid and reliable results to contexts other than the studied one.

Results

When trying to find an answer to our research question ´why agroforestry is implemented or not' we looked at different concepts and features or properties that are linked to the driving forces behind the farmers. Before finding the reasons, there was a need to interpret what was understood by the term 'agroforestry'. Once we identified the driving forces for implementing agroforestry and those for conventional agriculture, we searched also for the reasons to remove trees from the landscape, and the key barriers that the farmers face when practicing agroforestry. In brackets and italics we quote the most relevant comments from the farmers related to the explained results.

Farmers' concept of agroforestry

The most common definition by the farmers across Europe, for both agroforestry and non-agroforestry farmers, was that it is 'a combination of trees and other crops or animals'. This definition was generally accepted without providing major details, though it is recognized that variations exist between their definitions, e.g. 'trees integrated with arable land or livestock', 'trees in the fields', 'forest and agricultural productions in the same land', 'combination of forests and livestock'. Nevertheless, some farmers have shown a more comprehensive knowledge of what agroforestry is, giving more details on the concepts, e.g. including woody vegetation as one of the components, not only trees but also shrubs, in combination with agriculture (grasslands/pastures) and livestock (e.g. dehesa), obtaining revenues from different sources or products (cattle, sheep, goat milk and meat, fruit trees, timber, biomass, crops…), coming from at least one product from the understory.

> In society, agroforestry is a new word for something extremely old and large. For example, hedgerows in this country, but there are systems even older than that. They have seen evidence of stone age hill systems in Devon, UK which resemble alley cropping - Devon hedges 12 m apart going up a hill side. People do not recognize the extent of agroforestry at the moment e.g. reindeer farming on 10's of million ha. (UK3_AF_LA)

Results also showed that the concept of agroforestry was not clear for many conventional farmers that do not practice agroforestry. Some farmers defined it as growing trees, others related the definition with the promotion of trees in agriculture, while others thought that it is about integrating woodlands with crops (i.e. apple rows in crops), planted forest with arable field like corn or wheat, or grazed forest. Other farmers referred only to particular practices that were familiar for them: trees planted in strips, plantation for biofuels, or as short rotation coppice. Actually, in many cases, agroforestry was a concept that had never been heard especially by conventional farmers. What was more striking was that there was a lack of awareness among the agroforestry farmers, as many of the them were not aware of the term or concept of agroforestry, despite implementing the practice in their own farms. This confirms the need to implement communication and education for farmers, advisors and policy makers concerning agroforestry issues.

Driving forces for implementation of farming practices

The interviews aimed to identify whether there were divergent or convergent reasons for both conventional and agroforestry farmers to have decided on their farming approach.

The three main drivers observed for implementing *conventional farming* were tradition, the lack of knowledge on agroforestry and easier management. Tradition was the main reason to continue the farming as it was inherited or that was common in the region. It was what they knew works, as they were exposed to that practice. They might have chosen more sustainable agricultural practices, i.e. organic farming, but they lacked knowledge on what agroforestry is, how to implement it, the technical design, and its economic viability. In relation to the lack of knowledge, most of the farmers did not consider agroforestry as an economically viable option, requiring also a higher investment for establishment and maintenance. Furthermore, they did not see any added value from the agroforestry products, considering that there was no demand in the market for agroforestry products and that the crop production would be reduced if trees were present.

Farmers used to choose practices that receive subsidies, although they were not aware of the subsidies for agroforestry, which, in any case, are rather limited.

Conventional agriculture was also considered easier to manage, and better known. Farmers perceived that management issues are the main constraints to limit agroforestry adoption. Some of the farmers also considered that having animals makes it more complicated for having to find feed for the animals during winter, trees complicate mechanization and sometimes trees are not compatible with grazing. For instance, in grazed apple orchards animals had to be taken out of the system during several months because of spraying with herbicides. Thus providing an area for the animals during these months can be difficult for many farmers.

> Mechanization was the main reason not to put trees. (FR_A_AA)

Presence of trees on arable lands obstructs mechanization and for this reason trees were removed from rural landscape since industrial agriculture was adopted in more intensive agricultural areas. Some farmers considered that agroforestry needs more time dedication, that there is more work to be done and they lack the time and human resources to work on the farm, confirming that agroforestry systems are complex systems that require specific technical skills. If the plots are small, farmers did not consider other farming options as profitable, at least with the current CAP payment scheme. On the other hand, high quality soil is a scarce resource to be maximized, thus many farmers having a very productive soil preferred to maximize its production and use it only for agriculture. They considered that if trees occupy very valuable land, an expensive resource, agroforestry then becomes for them an opportunity cost.

> Land is a very valuable scarce resource, for which the production must be maximized, especially if it is a high-quality soil, or if the plots are small. (DE_A_HNVC)

Another driving factor influencing the type of farming was the farmer age. Farmers that were close to retirement were not interested in new types of farming and would keep doing what they have done their whole life. Young farmers were more interested in introducing innovative practices (García de Jalón et al. 2013). Ownership of the land was also a limitation, as farmers that rent the land cannot introduce trees as the owners do not usually want to plant any trees.

Interestingly, many farmers were interested in the agroforestry practices introduced by the interviewers and considered giving it a try after the interviews, but would need to see examples that those practices are profitable to decide to invest in those, and see other advantages.

Moving into the *agroforestry* farmers' vision, many different reasons were identified by the different farmers in deciding to implement agroforestry, while the three main drivers were tradition, diversification of the products and learning from others. Again, similar to conventional farmers, the tradition in the family or in the region, influenced the decision of most of the farmers to continue with the existing traditional agroforestry system. Behind that, there are cultural reasons and the acknowledgment of the benefit of the synergies between the different components. Agroforestry provides a diversification of products (wood, fodder, meat, milk, crops), which contributes to increase the production and the profitability of the farm with several lines of income, maximizing revenues and reducing some costs e.g. associated with land clearing. Agroforestry produces fodder for the animals in winter time and pastureland instead of useless dense shrubs. Furthermore, products obtained in agroforestry were always identified as high quality products. The diversification of products and synergies among the components (trees, animals and crops) was valued as decreasing the risks in crop production due to weather events or market changes.

> Pastures without trees are more vulnerable to weather conditions. (PT_AF_HNCV)

Learning from others and seeing the benefits was an encouraging driver to implementing agroforestry practices. Sources of learning were varied: attending a meeting, working abroad, colleagues or other farmer experiences, internet, etc. Also research initiatives led to new agroforestry farms, as farmers were contacted for research purposes and their farms used as demonstration plots.

Unproductive soils do not provide significant crop production, and small fields in difficult areas are hard to manage, thus agroforestry became an alternative in marginal lands, which at the same time improves soil condition (fertility) and increases biomass production. Under this point of view, in many marginal areas agroforestry systems are relevant for keeping a human presence in most remote areas by providing a low but sustainable source of income. In many marginal areas intensive agriculture was not possible due to limiting factors (poor soils, slope morphology) and in these conditions agroforestry can be a valuable alternative. Thus, agroforestry offers a sustainable alternative that can lead to a reduction in rural land abandonment.

> The silvopastoral system was introduced because arable crops are not convenient, due to the poor production, in marginal lands. (IT_AF_SP)

Agroforestry improved the environment around the farm, providing shelter for animals and birds, was good for the environment and nature conservation in general, including a solution for the pollination of trees. Hedgerows, for instance, protected from wind and water erosion, animals decreased the risk of forest fires, with associated cost reduction for land clearing.

> I started to combine apple trees with beekeeping to increase pollination because the trees had pollination problems. (ES2_AF_HNV)

Agroforestry had a high aesthetics value for the farmers, and because of their different components, it was considered as a nice landscape and as part of the cultural heritage. Some agroforestry systems may result in more tourism in rural areas and more rural employment, thus motivating farmers. Some aware farmers defended animal welfare (less stress, better quality feed) as a priority, e.g. poultry grow in their natural environment and lambs receive shelter in their first days. For instance, silvopastoral systems increase animal welfare, especially in Mediterranean hot summers where trees provide shade to animals.

Agroforestry was considered as a complex system that provides a more efficient management of resources and increases sustainable eco-intensification. Sustainable production was given priority over conventional agriculture when it was a second occupation, and not the primary source of income, given that it might not be as productive as conventional farming, chosen when there was pressure to make profit. Agroforestry perfectly matched the need to promote multifunctional agriculture as stated by the main international agreements and institutions.

Subsidies were also an incentive to apply agroforestry, to ensure the farms were profitable. Furthermore, different laws and regulations, like e.

Table 4 Drivers for practicing conventional farming

Driving factor	FR	ES	DE	PT	HU	EL	UK	IT
Tradition	●	●	●				●	
Lack of knowledge on AF		●	●	●		●	●	
Profitability		●	●	●		●	●	
Not aware of subsidies for agroforestry						●		
Easier management	●			●		●	●	
Less time dedication		●				●		
Small plots		●	●			●	●	
Scarce high quality soil			●	●				
Age		●						
Rented land			●					
Willingness to try AF	●	●	●	●		●		

The symbol ● in the cells indicate which driver was identified by the farmers in the different countries

Table 5 Drivers for practicing agroforestry

Driving factor	FR	ES	DE	PT	HU	EL	UK	IT
Tradition		●	●	●	●	●		●
Diversification of products		●	●	●	●		●	
Learning from others		●	●				●	
Marginal lands	●		●					●
Improving environment		●	●	●	●			
Landscape coherence	●		●					
Aesthetics value for tourism			●	●	●		●	
Animal welfare		●			●		●	
Use existing fences							●	
Quality of life		●						
Research purposes			●				●	
Sustainable eco-intensification				●			●	
Second occupation			●					
Subsidies		●					●	
Regulations			●					

The symbol ● in the cells indicate which driver was identified by the farmers in the different countries

g. on hedgerows in Germany might impose restrictions on applying other practices rather than the existing ones.

> The system is historical. The hedgerows were already established 300 years ago and are protected by the law. It is not allowed that they are removed. I am an agricultural farmer and if I could I would remove them. (DE_AF_HNCV)

To summarize the above described results, Tables 4 and 5 reflect all the driving factors identified by the farmers across the different countries in Europe.

Removal of trees from the landscape

Agroforestry farmers did not see any problem having trees on grasslands, but the first reason for removing trees and shrubs was to facilitate management to establish and maintain their grasslands and having wood pasture instead of having a dense shrub land. Some obstacles that trees may generate are the difficulty of using tractors or machines for establishment and/or maintenance of the pastures due to the distance between trees, or the damage that limits tree regeneration due to the presence of the animals. Some farmers have removed a few fruit trees growing on the farm boundaries because they were an impediment for farm machinery. At the same time, some farmers considered the trees as a focus of diseases, and attracting birds that eat the seeds.

> In order to protect cork oak roots I am not able to use disc harrow and instead have to use mounted knifes or chains. This last equipment is more restricted when wanting to renew the pastures. (PT_AF_HNCV)

Trees have been also removed from the fields as part of tradition, or to establish a more profitable new crop, e.g. olive trees. Only a few farmers mentioned eligibility for CAP subsidies as the main reason to remove trees from their land, to avoid the reduction of the funded area. In the new CAP (2014–2020) tree densities up to 100 trees/ha is allowed without a reduction in the funded area, as the CAP recognizes the role of hedgerows and isolated trees in arable lands.

Regulations may further limit the removal of trees. In some cases, it was not allowed to remove trees in the state owned forests, the forest service did not allow any intervention, and rarely permitted any tree removal, as was the case in Greece. The hedgerows could not be removed either in Germany.

> We would gladly remove some trees growing in our grasslands which reduce the available grazing land but we are not allowed to by the forest service. (EL1_AF_HNCV)

In any case, in most of the interviews, both agroforestry and non-agroforestry farmers reported that they had not removed any trees from their farms on a voluntary basis.

Key barriers restricting agroforestry

When interviewing the agroforestry farmers, three major problems on the implementation of agroforestry were highlighted: problems with farm management, regulation problems and lack of knowledge. Many farmers saw some difficulties in management, as agroforestry is more difficult compared to conventional agriculture, but did not consider those as barriers. The main problem was that it was hard work to start an agroforestry farm and/or renew an abandoned area, it usually needed high economic resources and was time demanding.

Other management issues included: higher management costs of the animals, difficulties in finding a good shepherd, bureaucracy becomes a burden (land and animal registrations, land delimitation and so on), fencing from wild animals required, decay of cork oaks, natural regeneration, problems with the quality of the pastures where the cows feed because climate fluctuation makes it difficult to provide food only with pastures and frequently they have to buy additional food in the summer to feed the cows, hard to count and look after the animals in the orchards.

> I cannot invest or do anything different from what I do right now due to lack of help. People come and work only for some days and then leave. (EL1_A_HNCV)

Wild animals (wolves, wild boars) represented another relevant management problem, which was connected to the abandonment of agricultural lands. Recently many lambs were killed, for instance in Italy. Sheep suffered stress and thus production was reduced. Due to the frequent attacks, sheep were housed in barns during the night, but this was not enough to prevent damages from wild fauna. On the contrary, when the wild fauna was not a problem, sheep were left in the open field for the whole time. Preventive measures and monitoring of wolves presence should be carried out by local public institutions.

Some farmers complained about the administrative burden and slow response from the administration for permission to establish new systems and on the CAP limitations and complexity. Moreover, not all farmers were aware of the possibility of establishing agroforestry systems in the frame of the Rural Development Programmes of the CAP.

Low profitability and product price fluctuations were also mentioned as problems, as well as low demand due to the financial crisis, together with high costs of establishment (fencing, protectors), changing to breeds more compatible with the trees, the long term required for returns (i.e. 15 years from apple trees for a good fruit production). Many farmers perceived a need to create a label for agroforestry products.

In any case, it was positive that many of the remaining farmers did not identify any problem while managing their agroforestry farms.

Discussion

The thematic narrative analysis derived from the data aimed to identify the driving forces affecting 'why agroforestry is adopted or not'. Among several reasons, the study shows that the major driving forces are tradition in the family or the region, diversification of products that agroforestry provides, and learning from successful and inspiring experiences.

There are not many studies apart from Graves et al. (2009) on the driving forces behind farmer's behaviour, as regards to agroforestry farming, at the European level, but there are some studies in particular regions or socio-economic environments (Sereke et al. 2016).

Domínguez and Shannon (2011) state that land owners manage their lands with four axes in mind: economic expectations of the property, ethical reasons, how the land should look, and natural risks. The relationship between socio-psychological factors (e.g. cultural, demographic, economic, and social variables, including ancestors, peers and education) and how people make decisions in practicing agroforestry are inseparable, and must be considered if policy makers, extension agents, and agricultural educators hope to influence and improve landowners' agroforestry management (Saha et al. 2011).

Based on the responses of the conventional farmers in this study, three major drivers for implementing conventional farming instead of agroforestry were tradition, the lack of knowledge on agroforestry and management simplicity. Nevertheless, other factors affecting the decision were economic viability, existence of subsidies, time needed for dedication, high quality soil, as well as age of the farmer and ownership of the land. Past research has shown that land ownership is frequently a barrier to adoption of innovative practices (e.g. Knowler and Bradshaw 2007; García de Jalón et al. 2015). One of the reasons for not establishing agroforestry was that when planting trees, the land would be tied up for future uses. This finding appeared as the most important factor in the study performed by Flexen et al. (2014) in Ireland, showing that farmers, both agroforesters and non-agroforesters, would consider planting trees in their plots, if there were greater financial incentives, or if they had land that was poor or unsuitable for farming (Flexen et al. 2014). A common attitude found amongst many farmers, both in our study and the previously mentioned study, was that farmers did not seem to plant trees in rich soils because of a lower farm net margin. They stated that they would only plant trees on marginal land where farming was difficult or unprofitable. Several studies examined the attitudes of UK farmers to planting farm woodlands (summarised in Doyle and Thomas 2000). In general, these studies showed that most farmers viewed forestry as an inappropriate use of productive land and irrelevant as an alternative source of income, primarily because planting incentives for conventional forestry were seen as inadequate to remove land from farm production. Doyle and Thomas (2000) suggest that as agroforestry involves the diversification of existing agricultural systems, and maintains the majority of the land area in agricultural production, it should encounter less resistance from farmers. They note that a key limitation is a lack of awareness of agroforestry among farmers.

To motivate farmers to manage more complex agroecosystems that are fundamentally different to their current simplified systems is challenging (Pannell 1999). Interestingly, many farmers interviewed in this study showed interest in the agroforestry practices and considered implementing it in their farms. This reflects openness and willingness but a lack of knowledge that the farmers have on alternative farming options; they would need to see examples that those practices are profitable and have many other advantages before deciding to invest in them. In order to attract farmer interest in investing lands with agroforestry systems, local demonstration plots where agroforestry practices are tested would be worthwhile. Some farmers would implement agroforestry practices if there were economic supporting measures, if they would perceive that the management was simple and if there would be approval from landowner in cases were the managed land is rented. For these reasons, it would be beneficial to establish and/or reinforce networks among stakeholders in order to facilitate the flow of knowledge. Innovative farmers can find empirical solutions to their problems and experiment themselves with agroforestry practices.

The results in this study are in line with Saha et al. (2011) which indicate that farmers' decision-making processes were most influenced by factors such as ancestors and education, followed by peers, financial condition, and economic importance of the agroforestry land holding. The attitudes of nature conservation managers, who are actually the farmers of the protected areas, towards implementing agroforestry management based on traditional ecological knowledge was determined by ancestors and childhood memories, mainly by their own experiences, and not their studies (Varga et al. 2016).

When looking at the agroforestry farmers' drivers, also tradition and learning from other experiences appeared as main reasons for implementing agroforestry, together with diversification of products, which reduces the risk in production, another relevant aspect for the farmers. These main drivers contrast with those of farmers in other European regions not included in this study, e.g. Switzerland, where the primary motivations were habitat function, both for biodiversity conservation and shade for livestock (Sereke et al. 2016). Nevertheless, animal welfare was also mentioned as an important driver among the farmers interviewed. Animal health and biodiversity also played a role in the motivations of farmers in Estonia (Roellig et al. 2015). Most farmers believed their animals thrive better in a more "natural" environment, needing less medication. In a similar study in Ireland, most of the agroforestry farmers rated landscape improvement and environmental factors as very important factors, as well as provision of shelter for livestock (Flexen et al. 2014).

The farmers in the current study considered agroforestry as a good alternative for low productivity marginal lands. Improving the environment, aesthetic value and quality of life were further reasons for implementing agroforestry. Similarly, the motivation to conserve cultural landscapes through agroforestry was lower among non-adopters in Switzerland compared to adopters (Sereke et al. 2015). Other studies in France revealed that the difficulties in accessing the land and the need to reduce agricultural inputs through functional biodiversity and diversification motivated smaller farmers to combine annual plants and fruits with the aim to increase their plot performance on a multifunctional basis, increasing the number of such plots significantly in the last few years (EURAF 2015).

Existing subsidies also encouraged farmers to manage the land in certain ways. Some farmers in this study chose practices that receive subsidies, although many were not aware of existing subsidies for agroforestry, which, in any case, are rather limited. The European Commission recently recognized the social and environmental value of agroforestry systems (EU Reg. 1698/2005) and a specific measure (M222) supporting agroforestry was introduced in the 2007–2013 CAP. The measure (M8.2) was improved in the 2014–2020 programming period (EU Reg. 1305/2013) and it is expected that its uptake would increase in the next few years. Furthermore, other studies have shown that the availability of grants did appear to influence those who are already interested in planting trees on the fields but not those who are not (Lawrence et al. 2010). Roellig et al. (2015) identified in Estonia that the determining factor to encourage management or restoration of wood-pasture was financial support. On the other hand, most farmers had a clear passion for managing their land and were proud of maintaining their wood-pastures following local traditions.

Regulations, on the contrary, might limit the use of different agroforestry components (e.g. hedges) and lands. These reasons were observed also in Switzerland with policies shifting from promoting trees or not on farms (Sereke et al. 2016). The perceived behaviour revealed that farmers felt rather free to decide whether to practice agroforestry or not, but they believed that framework conditions do not allow adoption. Environmental regulation was not a motivation, then, for both adopters and non-adopters.

Thus, although factors such as stewardship or farmer image might motivate a small number of farmers to use agroforestry systems, on a wider scale, voluntary adoption of agroforestry systems may need to be encouraged through subsidies, tax relief, or cross compliance, and compulsory adoption through government strategic plans, or penalties for non-adoption (Pannell 1999). Sereke et al. (2016) also justify subsidies for ecological production, and incentivize the local and indigenous agricultural products. Public support for land management is justified when such management provides public goods, e.g. environmental or social benefits such as rural vitality (EBCD 2012).

In order to encourage farmers to take up agroforestry, it is necessary to raise awareness among the farmers about the benefits of these practices, showing them examples of successful farms. Limited awareness of agroforestry among farmers and landowners was identified in the current study and by a number of other studies (McAdam et al. 1997; Doyle and Thomas 2000). For example, in a study by Graves et al. (2009), only 33% of farmers correctly defined agroforestry as the integration of trees with crops or livestock systems. These studies showed, however, that when farmers were shown agroforestry systems, their level of interest increased. Farmer-led projects have greater credibility in the eyes of other farmers (the peer-to-peer effect), thus one channel for raising awareness is to update the extension services with the latest developments and findings for further knowledge transfer. It was proven by Primmer and Karppinen (2010) that technical solutions suggested by technicians from extension services are incorporated by farm owners into their decision-making. Technicians are a relevant influencing agent for the owner to decide on the different management alternatives, in particular in cases with high uncertainty and complexity, e.g. price fluctuations and climate change (Schläuter and Koch 2009). Hauck et al. (2016) indicate that at the local level, technical journals were an important source of information for farmers, advising them, for example, on the different agri-environmental schemes that were available, while linkages between farmers and all stakeholders for exchanging information are encouraged.

There is also a clear need for raising awareness among the consumers, for them to give priority to agroforestry-derived products despite of higher prices, which in turn becomes an incentive for farmers. Duesberg et al. (2014) also recommended that, in addition to monetary incentives, policy tools such as image and information campaigns should be used. A broader knowledge about ecosystem services needs to be made available to farmers and to the society at large, to increase recognition of local ecological solutions (Sereke et al. 2016).

There are though, several limitations to the validity of the results in this study, due to wide variety of interpretations from multiple researchers doing the analysis. In addition, with thematic analysis, nuanced data could be easily missed. Furthermore, the flexibility of analysis makes it difficult to concentrate on which aspect of the data to focus on and the discovery and verification of themes and codes mixed. Finally, yet importantly, there is limited interpretive power and generalizability if analysis excludes theoretical framework (Guest 2012), and there is a small degree to which the results of this qualitative research can be generalized or transferred to other contexts or settings.

Conclusions

The main driver for the farmers, both conventional and agroforestry, to apply conventional or agroforestry farming, was the tradition in the family or the region and to continue with the existing traditional system. Knowledge of existing successful practices was also an encouraging driver for the uptake of agroforestry practices. Interestingly, there was a lack of awareness of agroforestry, as many of the farmers were not aware of the term or concept of agroforestry, despite implementing the practice in their own farms. Furthermore, the lack of knowledge led to misconceptions or wrong assumptions, as it was observed in the perceptions the farmers have on agroforestry practices. Many farmers would be willing to implement agroforestry if they would have more knowledge on those available, their profitability, benefits and practical know-how.

Undecided farmers would like to apply or expand agroforestry in their farm if the systems would be rewarding from an economic point of view. Only a few farmers considered the eligibility of their land for existing subsidies as the main reason to remove trees from their land, to avoid the reduction of the funded area. Subsidies within the CAP should favour this type of farming with more measures, which should also be explained thoroughly and encouraged by the extension services, increasing the awareness of grants available besides the practical knowledge on management and alternatives. Raising awareness of consumers on the quality of the agroforestry products and the ecosystem services provided by the agroforestry systems is also essential for encouraging farmers to practice agroforestry.

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Driving forces for agroforestry uptake in Mediterranean Europe: application of the analytic network process

Marko Lovrić · Mercedes Rois-Díaz · Michael den Herder · Andrea Pisanelli · Nataša Lovrić · Paul J. Burgess

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Abstract The factors that determine the implementation of four alternative agroforestry practices or no agroforestry on a theoretical 200 ha farm in Mediterranean Europe were examined using an analytic network process (ANP) model. The four agroforestry practices considered were implementation of a form of (i) high natural and cultural value agroforestry, (ii) agroforestry with high value trees, and agroforestry for (iii) arable and (iv) livestock systems. The ANP model was developed in a participatory manner through a systematic series of quantitative questionnaires and workshops with agroforestry researchers. In general, all the Mediterranean agroforestry systems were associated with high benefits and opportunities, but also with high costs and high risks. The greatest benefits were attributed to high natural and cultural value agroforestry systems, which greatly contributed to the highest priority of this system. Overall ranking of priorities for the agroforestry management alternatives show robustness in the sensitivity analysis. The "no agroforestry" land use became the preferred option when costs were given a weighting of 0.50 or greater.

Keywords Multiple criteria decision analysis (MCDA) · Analytic network process (ANP) · Mediterranean · Drivers

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Introduction

Agroforestry has been a common land use practice in Europe since early civilization. However since the industrial revolution it has often been replaced by intensive monoculture agriculture or forestry. Since the 1990s, agroforestry has been drawing increasing attention as a sustainable land use practice and there have been European initiatives to support and promote its uptake (Smith 2010). Nevertheless, although there are successful examples, the uptake of new agroforestry practices has been limited (Pisanelli et al. 2014; Luske et al. 2016). The decisions of farmers on whether to implement agroforestry on their farms depends on many socio-economic and environmental factors (Camilli et al. 2017, Garcia de Jalón et al. 2017, Rois-Díaz et al. 2017).

In Europe, the greatest extent of agroforestry occurs in Mediterranean regions (den Herder et al. 2017). Agroforestry in this area is a complex assemblage of different land covers resulting from the activities of humankind over many millennia (Antrop 2004). Many of the traditional systems are recognised for their high natural and cultural value such as the dehesas in Spain, the montados in Portugal, and wood pastures in Sardinia, Italy. Agroforestry, with varying level of complexity, is also practised in intercropped or grazed olive orchards in Italy and Greece, where olive trees are often mixed with oak, carob, walnut, almond and other fruit trees (Eichhorn et al. 2006).

In many marginal rural areas, farmers believe that agroforestry is still the most appropriate land use as the poor quality of the land means that intensive monoculture systems are unsustainable. In these areas, trees have traditionally contributed to the rural economy through the production of fruits, fodder and wood for fuel, litter or timber (Mosquera-Losada et al. 2009, Rigueiro-Rodríguez et al. 2009). In addition, they have amenity value, provide shade and shelter for workers and livestock, and reduce erosion by wind and water (Palma et al. 2007, Reisner et al. 2007). Despite this, the composition and arrangement of Mediterranean agroforestry systems are significantly affected by urbanization, industrialization, logging, the EU's Common Agricultural Policy (CAP) and climate change (Simoniello et al. 2015).

European farmers recognise that agroforestry can provide environmental benefits (e.g. biodiversity conservation, carbon sequestration, soil erosion control, and landscape improvement) and increase production, diversify incomes, improve product quality, and provide business opportunities (Garcia de Jalon et al. 2017). However, at the same time, they perceive the complexity of agroforestry management (e.g. higher level of labour compared to monocultures, difficulty of mechanization) as a constraint (Camilli et al. 2016). The complexity of EU policy regarding agroforestry and the eligibility of such systems for Pillar I and II payments from the CAP can also discourage farmers. For example, trees in fields, rows and hedges could reduce Pillar I payments between 2007 and 2013 (Pisanelli et al. 2014). Despite some improvements in the current 2014–2020 round, the CAP can still undermine the practice of agroforestry (Mosquera-Losada et al. 2017).

Rois-Díaz et al. (2017) recently used farmer interviews to assess the factors determining the uptake of agroforestry. In the Mediterranean region, farmers reported that wild animals, such as wolves, were a problem and farmers were limiting the free-grazing of sheep to avoid attacks, with negative effects on the level and quality of meat and cheese production. Farmers reported that agroforestry products could be labelled or certified to compensate for higher costs. Mediterranean farmers, who do not currently practice agroforestry practices, also believe that agroforestry could play an important role in adapting to an increased incidence of extreme climate events such as heavy rainfall leading to flooding and landslides.

The aim of this research, undertaken alongside the study of Rois-Díaz et al. (2017), is to determine how different criteria affect uptake of alternative agroforestry practices in the Mediterranean region. In this research, quantitative inputs were obtained from agroforestry experts rather than qualitative inputs from farmers, and the results are generated through application of a multi-criteria decision making model (Analytic network process—ANP; Saaty 1996) and not from the inductive analysis of interviews. The decision to start an agroforestry practice entails economic, social and environmental considerations and there are complex implications of possible benefits, costs, opportunities and risks. It can be very difficult to adequately present the relations between all these elements only by (essentially qualitative) input from farmers and different stakeholders. The novel use of an ANP model used in this study tackles this complexity through decision scenario focused on how a theoretical 'typical' farm for the Mediterranean region could improve its management system by implementing one of five alternative management options, namely: (i) high natural and cultural value agroforestry systems, (ii) agroforestry with high value trees, (iii) agroforestry for arable systems, (iv) agroforestry for livestock systems and (v) no agroforestry.

Materials and methods

Analytic network process (ANP; Saaty 1996) is a generalization of the Analytic hierarchy process

(AHP; Saaty 1988). Both models are based on pairwise comparisons of its elements; but ANP has the benefit that any element of the model can be related to any other part of the model, whilst in AHP comparisons are done with respect to the element higher in its hierarchy. In this study an ANP model was developed with separate 'sub-models' (sub-matrices) for "benefits" (B), "opportunities" (O), "costs" (C) and "risks" (R). Benefits and costs entail criteria that are internal to the decision system and are focused on present, while opportunities and risks entail criteria that are external to the decision system and are focused on future. The decisions were based on a defined description of a situation and entailed a limited set of discrete alternative decisions.

Mathematically, the model is presented in the form of different matrices where all elements of the model are present both in rows and columns. The first and basic mathematical representation of the model is the 'unweighted supermatrix', in which the columns are the 'senders', and the rows are 'receivers' of the influence relation in the comparison of the model's elements (Saaty and Vargas 2006; Saaty 2008). This unweighted supermatrix can be separated into different symmetrical sections called components, describing different segments of the decision model. These components can be assigned with different weights, where the multiplication of the unweighted supermatrix with these weights produces a 'weighted supermatrix'. If the elements of the unweighted supermatrix are not separated into different components, then the unweighted supermatrix is the same as the weighted supermatrix. Multiplication of the weighted supermatrix by itself multiple times until the limit of the sum of all the powers of the matrix is reached (i.e. until all the columns are the same) yields the 'limit supermatrix'. The results of the model, i.e. the priorities of discrete alternatives, are stated in respective rows for each alternative in the limit supermatrix.

When the judgments, i.e. pairwise comparisons are made, they are stated in the form of a question. A classical form of a question would be: 'What is the relative importance/influence of the elements *A* and *B* ('sender' nodes) on element *C* ('receiver' node)?' The answers would be presented in a textual form matching the Saaty's fundamental scale (ranging from 1—equal importance to 9—extreme importance, where reciprocal values are used for inverse comparisons). Saaty (2008) discourages the use of values greater than 9 on the fundamental scale, as large numbers of possible elements in the comparison can lead to inconsistency of the scale's interpretation.

As indicated above, if two elements in a pairwise comparison are of equal importance, the selection value would be 1, and both elements would be assigned with priority 0.5. If one element is extremely more important than the other, then the selection would be 9 in favour of the dominant element. Their assigned priorities would be 0.9 for the dominant element, and 0.1 for the other one. For a model with multiple sub-matrices, overall priorities are calculated by relaying the respective BOCR priorities through a single formula. Commonly used formulas are either multiplicative (B*O/C*R) or additive negative (w*B + w*O − w*C − w*R). Saaty and Ozdemir (2005) report that the priorities obtained by multiplicative formula represent the best short-term results, and priorities obtained by additive negative formula represent the best long-term results. Other formulas for aggregation of overall priorities that are frequently used (Wijnmalen 2007) are multiplicative with weights as powers ($(B^w*O^w)/(C^w*R^w)$), as also recommended by Saaty (2001), and additive with weights as coefficients (w*B + w*O + w*1/C + w*1/R), where values of 1/C and 1/R are normalized to a 0–1 range. Linking the priority aggregation formulas to financial performance indicators, priorities attained through additive negative formula have analogies with a net cash flow, and priorities attained through additive formula with weights as coefficients have analogies with a net present value (Wijnmalen 2007). All these formulas are used in this study, so that readers can relate priorities gained through different formulas to their divergent interpretations.

The fact that any element in ANP can be related to its any other part allows for modelling of feedback loops between its elements. The feedback loops are inherent in complex systems, and their modelling is the main reason why ANP was designed (Saaty 2008). ANP was selected as the method for modelling possible uptake of agroforestry practices as such decisions encompass environmental, economic and social considerations, and feedback loops are one of the main characteristics of Human–Environment Systems (Scholz 2011). In the agricultural and forestry sector, Jaafari et al. (2015) used ANP to select the best wood extraction method for forests in Northern Iran, García-Melón et al. (2008) used it for farmland appraisal in Eastern Spain, Razavi-Toosi and Samani (2012) evaluated water transfer projects in the Karun River (Iran), and Wolfslehner et al. (2003) and Wolfslehner and Vacik (2008) assessed strategies for forest management in Austria. ANP can also be implemented in combination with other research approaches. For example Tran et al. (2004) combined ANP with a principal component analysis approach to rank threatened watersheds in the Mid-Atlantic Region of the United States. Catron et al. (2013) combined ANP with Strengths, Weaknesses, Opportunities and Threats (SWOT) to assess further development of biomass-based energy production, and Azimi et al. (2011) have used a similar approach to analyse mining strategies. ANP has been applied in hundreds of decision-making situations in a wide range of fields many of which are presented in three volumes of the Encyclicon (Saaty and Ozdemir 2005; Saaty and Cillo 2007; Saaty and Varas 2011).

Model design

The ANP model was designed with the objective to assess the priorities of main types of agroforestry practices in the Mediterranean context within the framework of different economic, social and environmental criteria. Senior experts in agroforestry from Spain, Portugal, Italy and Greece were asked to describe a typical farm from their country and some farm management alternatives, which became the basis for the decision making models. The farm descriptions were refined and revised by the experts in a participatory manner several times to ensure convergence. The description of the farm and the alternative management scenarios are presented in Table 1.

Ten senior agroforestry experts were asked to define a preliminary list of social, environmental and economic criteria that might affect agroforestry implementation. These results were then presented and discussed in a workshop of the EU-sponsored AGFORWARD research project with 22 participants that were predominantly agroforestry scientists, but also with participation from agroforestry associations and agricultural advisory agencies. Each person filled-in another questionnaire where the list of criteria was improved and their relations were drafted. A draft ANP model was designed and sent back to the same group for comments in a form of a questionnaire. Subsequently, the improved model was send back again to the workshop participants to assign pairwise comparisons between the elements of the model. Respondents also commented on the importance of individual criteria, their meaning and potential overlap, and also on the general structure of the model. The main comment was that the model's complexity needed to be reduced. By eliminating the criteria that were mentioned by the lowest number of respondents, the number of criteria was reduced from 54 to 35. Respondents received one last questionnaire which focused on 'critical' comparisons i.e. comparisons in which opinions of the respondents were divergent. The criterion for selection of a 'critical' comparison was that the priority vector value for at least one respondent diverged by at least 0.194 from the arithmetic mean of the priority, which is equal to sum of value of mean and of one standard deviation of the priority. The 'critical' comparison questionnaire comprised 26 out of a total of 73 direct comparisons in the model. Although 22 individuals participated in the first half of the model design, only eight respondents assigned pairwise comparisons between the elements of the model. For this reason, it would be prudent to state that the model was constructed with an input from eight decision makers—as this is a minimum number of people that have been involved in a single step of the model design.

After the last questionnaire, there were no more 'critical' judgments, and the design of the model was finalized (Fig. 1), where the final values of the pairwise comparisons were based on the geometric mean of responses. At this point, calculation of final priorities and sensitivity analysis was performed. A summary of this analysis was given back to the respondents, and they were asked to provide their feedback, describing and commenting (both qualitatively and quantitatively on a Likert scale) to what extent the presented results were an adequate representation of a real-life situation. The final model is a full BOCR model with 35 criteria, where the benefits sub-network was further divided into three clusters representing environmental, economic and social benefits. The Benefits sub-network was assigned the highest weight (0.354), Costs and Risks had approximately same the weight (0.239 and 0.221), and

Table 1 Farm description and management alternatives of the ANP model

Description of the theoretical farm
The decision to adopt agroforestry practice or not is considered by a farmer which owns a farm in the Mediterranean region. The farm size is 200 ha, at an altitude between 0 and 600 m, an annual precipitation of 500–660 mm, average annual temperature of 11 °C on cambisol soil with barley, wheat and alfalfa crops. A small forest (15 ha) of *Quercus ilex* belongs to the farm. Mechanization is possible due to the extensive flat lands. The owner is 55 years old, owns the farm, has low level educational qualifications, and currently implements traditional farming practices
Management alternatives
1. Implement high natural and cultural value agroforestry system
The farmer considers adopting a high nature and cultural value agroforestry practice in these systems. The farmer considers including hedgerows and forest strips to promote biodiversity and an increase of crop resilience and adaptation to climate change. The chosen woody species are *Quercus ilex* and *Juniperus thurifera*
2. Implement agroforestry with high value trees
The farmer considers adopting an agroforestry practice with high value trees. The farmer is looking for ways to increase the profitability of his farm and at the same time to improve ecosystem services. Part of the land will be planted with *Prunus* and *Juglans* trees (maximum of 100 trees per hectare to ensure the land remains eligible for CAP Pillar I payments). A management plan will be made with the objective to optimize high quality timber production. This will include a mid-term thinning of the stands, before final felling; pruning is done every year
3. Implement agroforestry for arable systems
The farmer considers adopting an arable agroforestry system. The farmer is looking for ways to diversify farm production to ensure a more stable income base for the farm. The farmer decides to plant fast growing trees like poplar (*Populus*) in the arable land up to a maximum density of 100 trees per ha to ensure the land remains eligible for CAP Pillar I payments. The tree rows are planted at a spacing of 12 m; along the rows the poplars are planted at 9 m
4. Implement agroforestry for livestock systems
The farmer considers adopting a livestock agroforestry system. The farmer is looking for ways to diversify farm production and is considering the combination of meat (lamb and beef), arable and forage crops to overcome season pasture deficits. Hedges of mulberry (*Morus alba*) trees with high quality forage value would be planted and sheep would be introduced in part of the arable land. Cattle will be introduced in the small forest of *Quercus ilex*. One large investment the farmer has to make is to fence the farm
5. Do not implement agroforestry system
The farm continues on with the same management regime as before, and no changes are introduced

Opportunities was given the smallest weighting (0.185).

Results

Selection of prioritisation formula

Although each of the four prioritisation formulas highlighted the high ranking of *high nature and cultural value agroforestry*, the relative ranking of the remaining four alternatives was affected by the choice of formula (Fig. 2). The additive negative formula, which is reported to provide the best "long-term" results (Saaty and Ozdemir 2005), resulted in much lower prioritisation of the other four alternatives compared to the other three formulas. In fact, with this method, no agroforestry (D5) had a negative priority. The prioritisation obtained with additive formula with weights as coefficients resulted in a minor change in ranking, as D4 (*Implement agroforestry for livestock systems*) has a marginally higher priority (0.991) than D2 (*Implement agroforestry with high value trees*; 0.933).

Benefits, costs, opportunities, and risks

Figure 3 shows that both the benefits and opportunities associated with the decision to implement agroforestry (D1–D4) were greater than those with the decision to not implement agroforestry (D5). However the agroforestry systems were also associated with greater costs and risks. The greatest benefits were attributed to *High natural and cultural value agroforestry systems* (D1), which strongly contributed to the highest overall priority of this system. The low

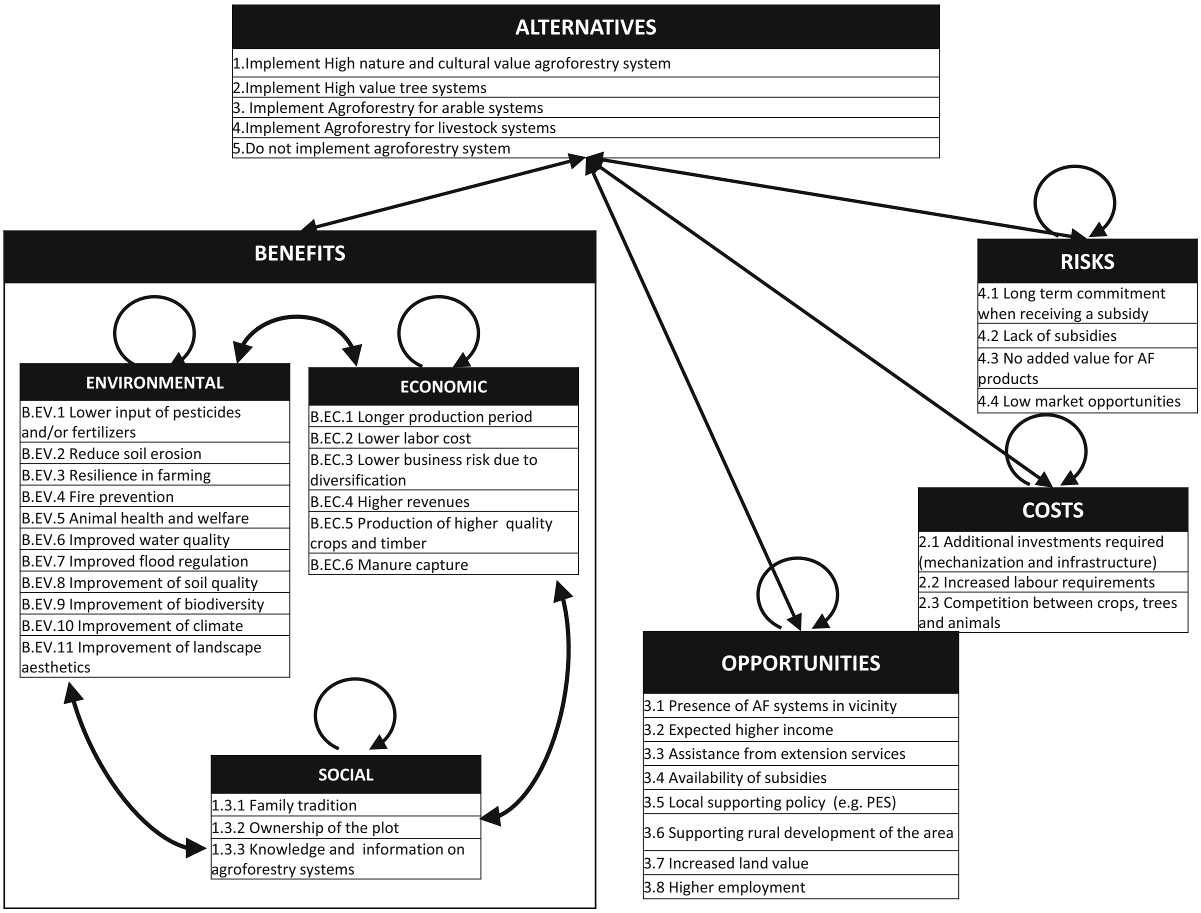

Fig. 1 The ANP model design examined five alternatives in terms of benefits, costs, opportunities, and risks. The benefits were considered within environmental, economic, and social areas

overall priority of *Do not implement agroforestry* (D5) does not stem from its low priority in individual sub-networks, but rather from the fact that the ratio of ideal priorities in the opportunities and risks sub-networks (1:2.72) is much more detrimental than is the case of other management alternatives (1:1.12, 1:0.86, 1:0.67 and 1:0.68 for D1 to D4, respectively).

The main environmental benefit criteria in determining whether to implement agroforestry, as defined by the interviewed experts, were lower input of pesticides, improved water quality, and improved flood regulation (Table 2). In terms of economic benefits, the production of higher quality crops and timber and lower business risk due to diversification were prioritised. Knowledge and information on agroforestry systems and family tradition were the main social benefits. The main opportunity criteria were higher employment and availability of subsidies. The main cost criteria were increased labour requirements, and competition between crops, trees and animals. The main risk criteria were low market opportunities and lack of subsidies.

In order to test the robustness of the results, a sensitivity analysis was first performed on the level of sub-networks (Fig. 4) using the additive negative formula. This sensitivity analysis shows increase of the priority of alternatives with increase of value of benefits and opportunities, and decrease of priorities to negative values with the increase in costs and risks. Although ranking of agroforestry management alternatives (D1–D4) show stability with the change of weights of the sub-networks, the same cannot be stated for No agroforestry (D5) alternative, as its relative priority (i.e. rank) increases with the decrease in the weight of Benefits and Opportunities, increases with the increase in the weight of Risks, and very

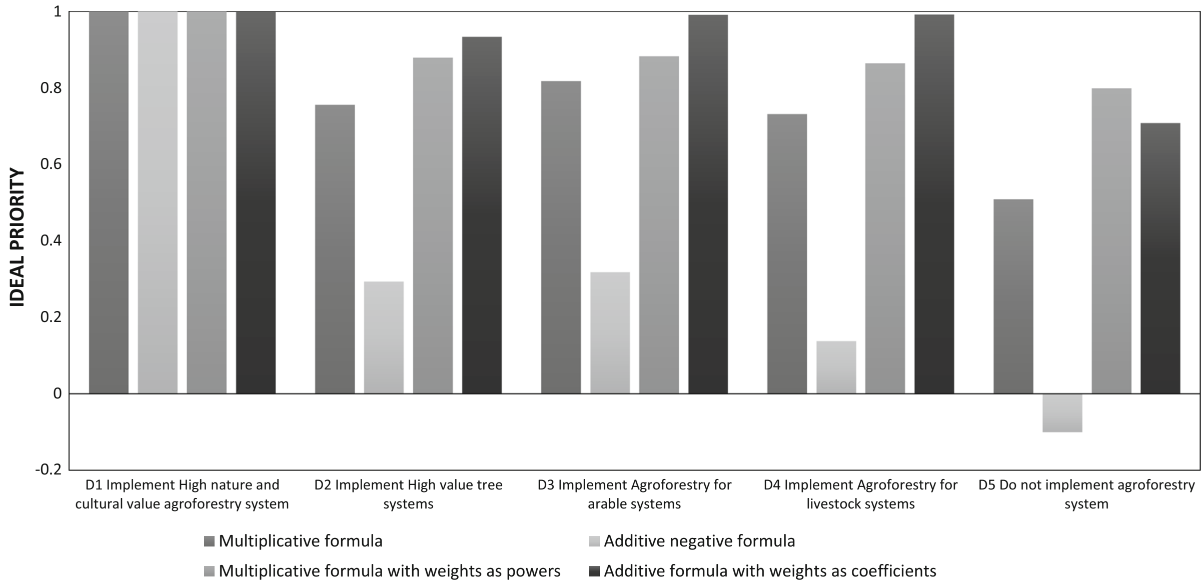

Fig. 2 The effect of four types of formulas for determining the balance of Benefits, Opportunities, Costs and Risks on describing five types of agroforestry decision in the Mediterranean region of Europe

strongly increases with the increase in the weight of Costs.

The next stage was to determine the sensitivity of prioritisation to five of the specific criteria, again using the additive negative formula. The node-level sensitivity graphs in Fig. 5 are for the five criteria where the sensitivity analysis caused a change of ranking on the level of the respective sub-network; and that has occurred for 5 out of 35 criteria, which indicates relative stability of priorities to the changing values of individual criteria.

For the five selected individual criteria, the ranking between the implementation of agroforestry systems compared to no agroforestry was consistent, with no agroforestry (D1) only outranking the implementation of agroforestry for arable systems (D3) when a very high weighting is given to "family tradition" (Fig. 5).

In the follow-up validation questionnaire respondents were given the results of the analysis, and asked 'Given your knowledge on agroforestry systems and with respect to the farm management scenarios, do you agree or not agree that the presented result is an adequate representation of a real-life situation?' This question was posed on a nine-point Likert scale, and asked separately for overall priorities under each aggregation formula, and separately for priorities under each sub-network. The mean value of answer was 7.62, which falls under 'Strongly agree' category.

Discussion

Prioritisation of agroforestry

The ANP model, on the basis of the assumed weighting given to benefits, costs, opportunities and risks, gave the highest priority to *High natural and cultural value agroforestry* (D1) and a low overall priority to *Do not implement agroforestry* (D5). Novel practices such as agroforestry with high value trees (D2), and the selected practice of agroforestry for arable (D3) and livestock (D4) systems also received higher prioritisation than not implementing agroforestry (D5). These results are reflected in the large extent of high nature and cultural value agroforestry in European countries in the Mediterranean zone. Such regions generally have the largest coverage of agroforestry in Europe, ranging from 10.9% of the utilized agricultural area in Italy to about 40.9% in Cyprus (den Herder et al. 2016).

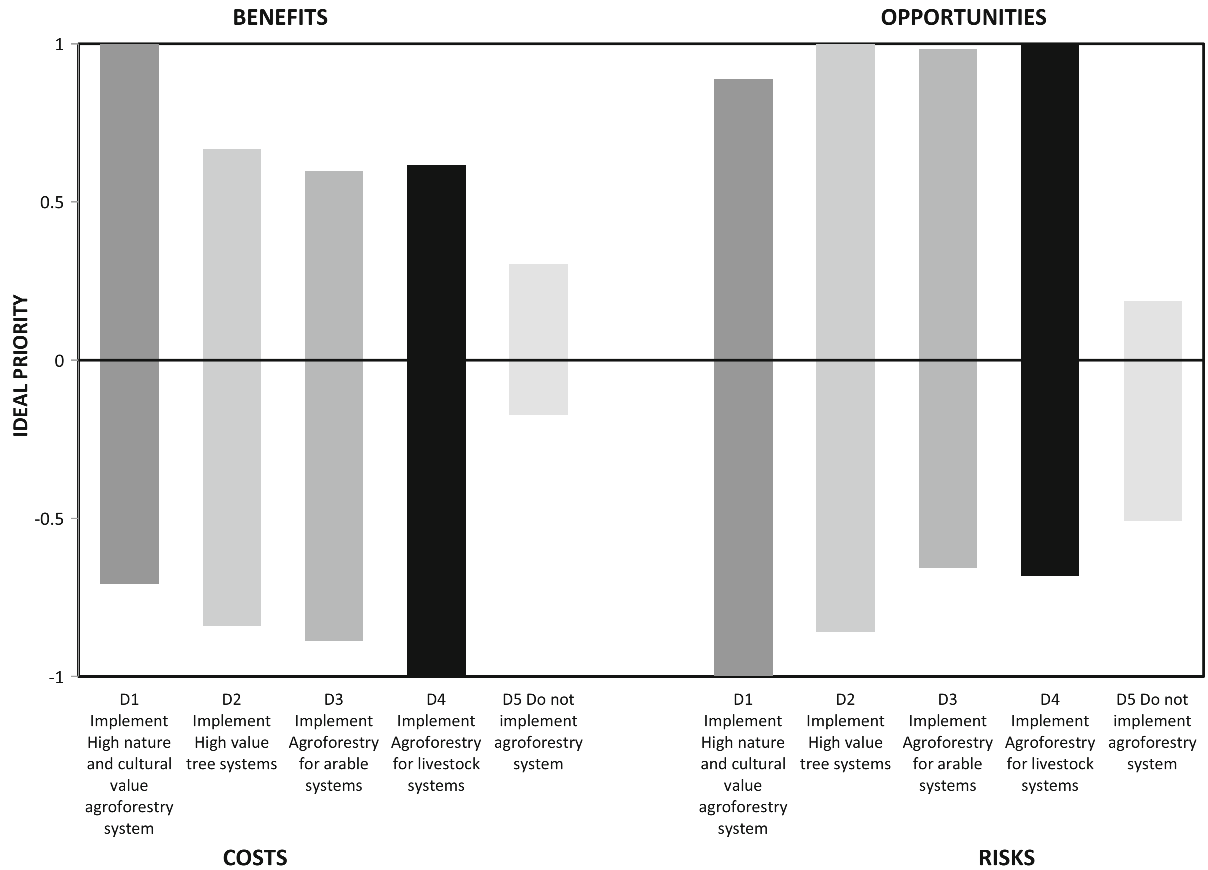

Fig. 3 BOCR ideal priorities for the ANP model

Our group of agroforestry experts perceived the most important environmental benefits as being a lower input of pesticides and fertilizers, improved water quality and improved flood regulation. By contrast the improvement of biodiversity, landscape aesthetics, soil conservation and animal welfare were given low priorities compared to those reported by Garcia de Jalón et al. (2017). The most important economic benefits were identified as lower business risk due to diversification and the production of higher quality crops and timber. This is consistent with the findings of Camilli et al. (2016, 2017), who reported that Italian farmers identified that the production of high quality products was one of the most important benefits of silvopastoral systems. It is also consistent with results on interviews with farmers reported by Rois-Díaz et al. (2017) who found that diversification of products, together with tradition and learning from others, was an important driver for the adoption of agroforestry.

Increased labour costs and competition between crops, trees, and animals were identified as the most significant costs determining the uptake of agroforestry (Table 2), mirroring the results of Sereke et al. (2015) and Camilli et al. (2016). The greatest opportunities were related to the availability of subsidies and assistance from extension services, and low market opportunities and lack of subsidies were seen as the greatest risks. Garcia de Jalón et al. (2017) in a pan-European study and Camilli et al. (2016, 2017) in a pan-Italian study also reported that the need for national demonstration sites and education programs to support the uptake of agroforestry. They cite the work of Pannell (1999) who identifies that a farmer considering agroforestry must (i) have the information about the system, (ii) be satisfied that it can be trialled, (iii) perceive that it is worth trialling, and (iv) and that it can support the objectives of the farm business, particularly profit. These conditions are not easily obtained in long-term

Table 2 Priorities of criteria normalized by three benefit clusters, and cost, opportunity and risk cluster for determining the uptake of agroforestry in Mediterranean

Cluster	Criterion	Priority normalised by cluster
Environmental benefits	Lower input of pesticides and/or fertilizers	**0.318**
	Improved water quality	**0.246**
	Improved flood regulation	**0.236**
	Improvement of soil quality	0.076
	Reduce soil erosion	0.059
	Resilience in farming	0.046
	Improvement of biodiversity	0.014
	Animal health and welfare	0.004
	Fire prevention	0.001
	Improvement of climate	0.000
	Improvement of landscape aesthetics	0.000
Economic benefits	Production of higher quality crops and timber	**0.455**
	Lower business risk due to diversification	**0.452**
	Longer production period	0.045
	Lower labor cost	0.025
	Manure capture	0.019
	Higher revenues	0.003
Social benefits	Knowledge and information on agroforestry systems	**0.552**
	Family tradition	**0.423**
	Ownership of the plot	0.025
Costs	Increased labour requirements	**0.531**
	Competition between crops, trees and animals	**0.469**
	Additional investments required (mechanization and infrastructure)	0.000
Opportunities	Availability of subsidies	**0.379**
	Higher employment	**0.311**
	Assistance from extension services	**0.241**
	Local supporting policy (e.g. PES)	0.040
	Presence of AF systems in vicinity	0.028
	Expected higher income	0.000
	Supporting rural development of the area	0.000
	Increased land value	0.000
Risks	Low market opportunities	**0.547**
	Lack of subsidies	**0.453**
	Long term commitment when receiving a subsidy	0.000
	No added value for AF products	0.000

The priorities of criteria from the limit matrices of respective sub-networks have been normalized so that their sum in the respective cluster is 1. Given the structure of the model, the cluster-level normalization is performed on the level of sub-networks for Costs, Opportunities and Risks, while for Benefits sub-network it is performed separately for three of its clusters

Values above 0.2 are indicated in bold

systems such as agroforestry, in particular where the high initial investment costs are readily apparent and the full financial benefits may only be observed over a long period.

In the qualitative interviews with farmers reported by Rois-Díaz et al. (2017), it was noted that some farmers who implemented agroforestry were unfamiliar with the term "agroforestry". This lack of

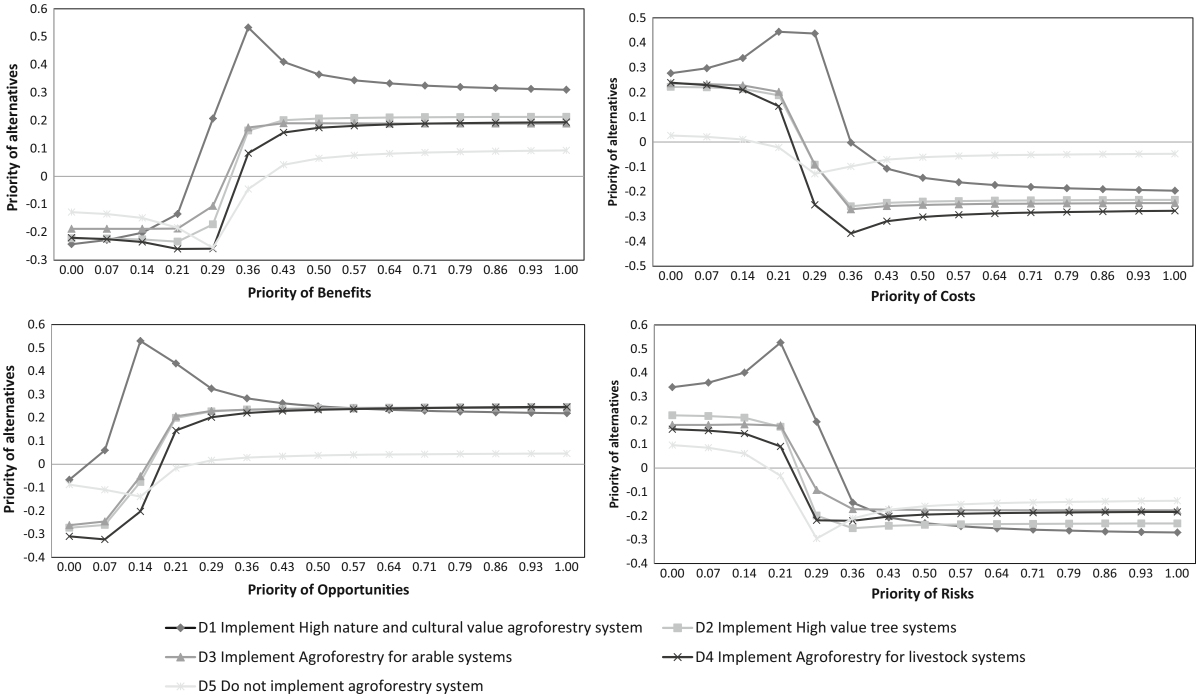

Fig. 4 Sensitivity analysis of the prioritisation of four agroforestry decisions (D1–D4) and the decision to not implement agroforestry (D5) in terms of the Benefit, Opportunity, Costs, and Risk sub-networks using the additive negative formula

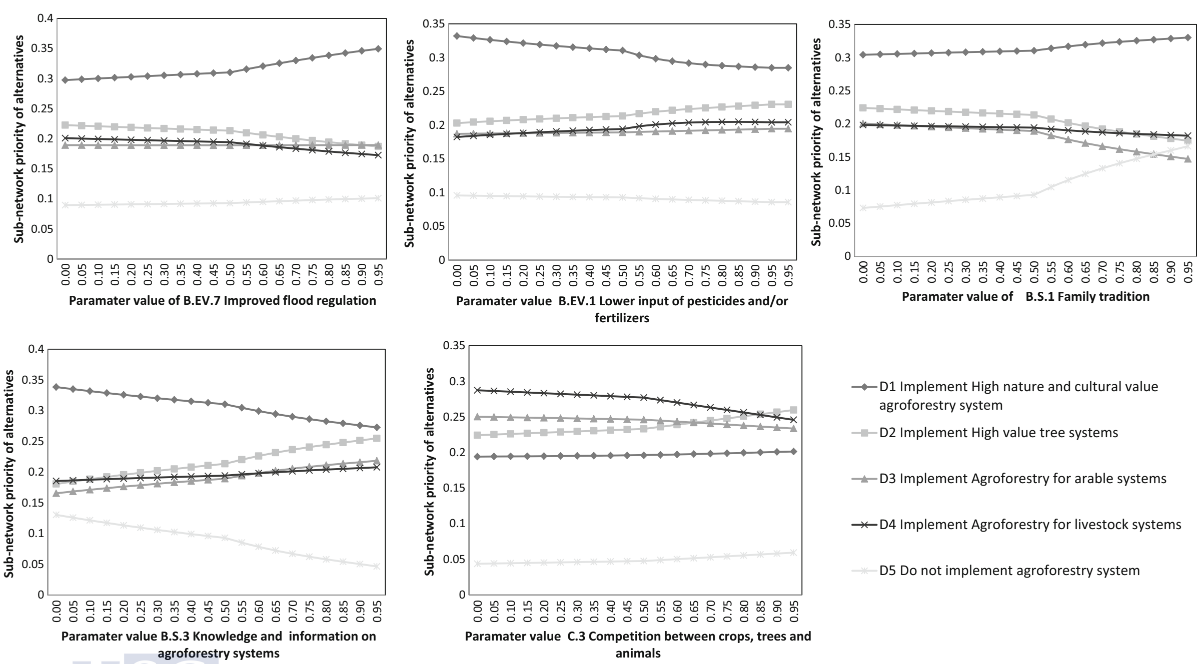

Fig. 5 Sensitivity analysis of the prioritisation of four agroforestry decisions (D1–D4) and the decision to not implement agroforestry (D5) in terms of five criteria: (i) improved flood regulation, (ii) lower inputs of pesticides and/or fertiliser, (iii) family tradition, (iv) knowledge and information on agroforestry systems, and (v) competition between crops, trees and animals

knowledge makes it difficult for a farmer to acknowledge the existence of the vast array of different criteria that are listed in the ANP model.

Rois-Díaz et al. (2017) reported on several variables behind uptake of agroforestry practices that were not included as criteria in the ANP model reported here. These were the age of the farmer (younger, rather than older, were more likely to implement agroforestry), income diversity (those with income from outside farming were more likely to implement), and tourism potential (farms with touristic potential were more likely to implement). A very similar approach to this study was taken by Camilli et al. (2017), where a comparable group of ‘agroforestry stakeholders’ (farmers, researchers, experts and policy makers) was asked on their perceptions on agroforestry in Italy, and where the feedback was generated through questionnaires administered in workshops, following a categorization of agroforestry systems that matches the decision alternatives in the ANP model of this study. Their study emphasized the importance of local supply chains for agroforestry products and management problems that might be caused by wild animals; issues that were not taken-up in this study. They also found that ‘stakeholders’ (mostly researchers), in comparison to farmers, have higher valued environmental aspects of agroforestry and downplayed the importance of management costs. However, on the overall range of descriptors of agroforestry, there was no statistically significant difference between the opinions of these two groups.

Robustness of results

The use of four different formulas for aggregation of overall priorities resulted in substantial changes in the ratio of the five alternative priorities (Fig. 2). By contrast the ranking of the five decisions was generally robust across the four formulas (D1, D3, D2, D4 with D5 having the lowest priority), although the additive formula with weighting transposed the order of D2 and D4. The sensitivity analysis also showed a robustness of priorities to changes in the weighting to benefits, opportunities, costs or risks.

In general the *implementation of high nature and value agroforestry* (D1) was the prioritised land use and overall D5 (*Do not implement agroforestry*) received the lowest priority. Alternatives D2-D4 offer smaller benefits than D1 (the benefit sub-network is given a high weighting), moderately high costs and risks (which are sub-networks given a moderate weight), and although they offer high opportunities, the opportunity sub-network was given a low weighting. The negative overall priority of D5 is not a strange result as it has lowest priority attained through all other aggregation formulas, and additive negative formula is the only one in which a negative overall priority is possible. The wide range of priorities attained through additive negative formula is also an expected finding, as it follows other results found in the literature; e.g. in Wijnmalen (2007), range of normalized priorities obtained by multiplicative formula is 0.102, from additive with reciprocals is 0.033, and from additive negative is 0.826. Saaty (2001) also states that multiplicative and additive outcomes may not always be close, and Saaty and Hu (10) demonstrate that they can have even different rankings.

Any research design has limitations to the validity of its results and this study is no exception. Potential limitations include the bias of the respondents, the selection of the default farm type and alternatives, and respondent fatigue.

Respondent bias: within the final model, the weighting given to Benefits (0.354) was greater than that to Costs (0.239), Risks (0.221) and Opportunities (0.185). The high weighting given to Benefits and the high benefit score for D1 (Fig. 4) contributed to the high ranking of the *High natural and cultural value agroforestry* alternative. It could be argued that this result could be biased because it is based predominantly on input from agroforestry experts whom have intrinsic positive prejudice towards agroforestry. This threat is somewhat alleviated by the fact that results of this study show resemblance to findings of Rois-Díaz et al. (2017), a study with same objectives but one that is also based exclusively on farmer’s input, including of those who do not implement agroforestry.

Selection of default farm type and alternatives: the reported results were developed with reference to the specified farm description and description of management alternatives, and not directly to the agroforestry in the Mediterranean region. We acknowledge that there cannot be a single farm description that is truly representative of the region, and this is the greatest validity issue of this study. We have designed the management scenario in a participatory manner, bearing in mind all the diversity that exists in agroforestry practised from Spain in the West to Greece in the East. However, this management scenario entails compromises between different viewpoints, approximations and inherently deviations from actual situation. For example, in the EU Farm Accountancy Data Network average farm size in the sample for seven listed Mediterranean countries is 29 ha with 5.5% of forests, while the farm in our description is about seven times bigger but it has similar (7.5%) forest coverage.

Respondent fatigue: the ANP model was selected as multi-criteria decision model due to its ability to capture complexity; but this strength also has some drawbacks. The experts involved may have understood the general idea, the relations between the elements and the pairwise comparison. However, they did not fully understood the calculation process and thus how priorities are generated. Many rounds of discussion and questionnaires may have caused respondent fatigue, especially for the questionnaire in which they had to judge 73 pairwise comparisons. The AHP that was presented as a basis for ANP, on the other hand, was completely understood by respondents. The problems caused by selection of ANP as the decision method is somewhat alleviated by the fact that respondents strongly agree that the results of the model 'are an adequate representation of a real-life situation'.

Conclusions

This paper demonstrates that it was possible to develop an ANP model to describe the key considerations (from the perspective of experts) as to whether a farmer implements four alternative agroforestry systems, or no agroforestry, for a theoretical farm in Mediterranean Europe. This quantitative approach was undertaken alongside quantitative surveys of the main positive and negative attributes (Garcia de Jalon et al., 2017) and qualitative surveys on agroforestry (Rois-Díaz et al. 2017). Whilst it would be simpler to implement an AHP model, rather than an ANP model, in this study the ANP model was selected because it can allow a superior depiction of complexity. Our study showed that implementing an ANP model is a significant undertaking and the development of the model could have been simplified by limiting the number of criteria, which in turn would reduce the number of pairwise comparisons and the risk of respondent fatigue. Hence we would recommend that ANP is only used in situations with a limited number of respondents, where there is opportunity for substantial feedback between the modeller and the respondents, and where the respondents have sufficient interest in the model so that they can provide input without significant fatigue.

On the basis of the assumed weighting to benefits, opportunities, costs, and risks; the ANP model resulted in the highest prioritisation being given to *high nature and cultural value agroforestry* and the lowest prioritisation to *no agroforestry*. This result correlates well with the high coverage of high nature and cultural value agroforestry found in Mediterranean Europe. The model, based on the response of eight agroforestry experts, indicate that family tradition, product diversification, and lower use of pesticides are important determinants for the uptake of agroforestry. Similar results have been obtained from other surveys suggesting that the ANP methodology and the results are valid.

Because of the substantial iterations required, the model was developed using the responses from primarily agroforestry researchers rather than farmers. This may have resulted in a longer list of environmental compared to economic and social benefits (Table 2), but the exposure of agroforestry researchers to a wider range of systems, than many farmers, may allow them to appreciate the important decision making processes in different scenarios. Conversely the approach means that the personal attributes of the farmer or decision maker (e.g. age, land ownership, sources of other income) are not considered. Another positive aspect of this quantitative, structured approach is a dissemination of decision criteria between those which represent current status (i.e. benefits and costs) and those which represent the future (i.e. opportunities and risks). Sensitivity analysis clearly shows that the appeal of classical farming practices fades away in comparison to different agroforestry practices when opportunities are strengthened and risks are diminished. These future-oriented criteria that go beyond the scope of an individual farming scenario are the type of criteria that the policy sphere can affect in order to strengthen the uptake of agroforestry practices, i.e. by focusing on key opportunities and risks as identified in the ANP model, namely (i) providing framework that ensures availability of subsidies; (ii) providing adequate support from extension services and (iii) supporting agroforestry branding, labelling or certification schemes in order to tackle the issue of low market opportunities for its products.

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ANNEX III. PUBLICATION 3 AND LICENCE

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Agroforestry in the European common agricultural policy

M. R. Mosquera-Losada · J. J. Santiago-Freijanes · A. Pisanelli · M. Rois-Díaz · J. Smith · M. den Herder · G. Moreno · N. Ferreiro-Domínguez · N. Malignier · N. Lamersdorf · F. Balaguer · A. Pantera · A. Rigueiro-Rodríguez · J. A. Aldrey · M. P. González-Hernández · J. L. Fernández-Lorenzo · R. Romero-Franco · P. J. Burgess

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Abstract Agroforestry is a sustainable land management system that should be more strongly promoted in Europe to ensure adequate ecosystem service provision in the old continent (Decision 529/2013) through the common agricultural policy (CAP). The promotion of the woody component in Europe can be appreciated in different sections of the CAP linked to Pillar I (direct payments and Greening) and Pillar II (rural development programs). However, agroforestry is not recognised as such in the CAP, with the exception of the Measure 8.2 of Pillar II. The lack of recognition of agroforestry practices within the different sections of the CAP reduces the impact of CAP activities by overlooking the optimum combinations that would maximise the productivity of land where agroforestry could be promoted, considering both the spatial and temporal scales.

Keywords Pillar I · Pillar II · Greening · Rural development programs · Cross-compliance

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Introduction

The common agricultural policy (CAP) is the most important driver of agricultural management and sustainability in the European Union. The CAP represents around 40% of the European Union (EU) budget, whose annual expenditure (in current prices) doubled from about EUR 30 billion in 1990 to EUR 60 billion in the CAP period 2007–2013. The European CAP has evolved from its initial inception in 1962 when it covered six countries. In 1973, the inclusion of the United Kingdom, Ireland, and Denmark increased this number to nine. Further additions were made in 1981 (10), 1986 (12), 1995 (15), and 2004 (25). The inclusion of Romania and Bulgaria in 2007 brought the total to 27, which finally amounted to 28 after the incorporation of Croatia in 2013, and which will return to 27 after the Brexit agreements. The CAP has now a direct impact on 14 million farmers, with a further 4 million people working in the food sector. One of the key CAP reforms occurred in 1992, when the 'MacSharry' reforms sought to limit the increasing cost of the CAP with a shift from product support (through prices) to coupled direct payments (through income support). The reforms also saw the reduction or complete removal of coupled payments, exports, refunds, and market support measures. The year 1992 also saw the introduction of the first directives that provided European support to the planting of forest trees on agricultural land. The Agenda 2000 reforms, signed in Berlin in 1999, emphasised the division of the CAP into a 'first pillar' based on single farm payments and a 'second pillar' focused on rural development measures. Following the CAP reform in 2003, payments were decoupled from the production of a specific product, while farmers would instead receive payments based on a set amount per hectare of agricultural land. The CAP has also aimed at becoming more environmentally oriented. For the 2007–2013 period, Pillar I across the EU-27 was worth just over three times the budget of Pillar II. However, differences existed between the CAP budgets for old and new Member States. Whilst the level of expenditure was relatively balanced in the 12 newest EU states (where the level of expenditure on both Pillars was almost the same), the EU-15 received five times as much for Pillar I than for Pillar II. For the 2014–2020 period, rural development and environmental issues will account to near 24% of the total CAP budget.

Nowadays, the CAP is designed to ensure food production within the sustainable FAO principles. The policy is written by the European Commission and has to be approved by the EU political bodies (Parliament and Council of Europe). Once approved, the CAP is implemented during a period of 7 years. The CAP is based on two main regulations, commonly called Pillar I and Pillar II, which were developed by Regulations 1307/2013 (EU 2013a) and 1305/2013 (EU 2013b) for the 2014–2020 commitment period. The global CAP budget is EUR 281.8 billion for the first pillar and EUR 89.9 billion for rural development (EU 2011). Pillar I is completely funded by the EU and initially linked to land productivity, while Pillar II is associated with the environment and co-funded by the Member States. Receiving support from any of the Pillars is conditional on the fulfillment of certain rules, termed Cross-compliance, which refers to minimum requisites on sustainability issues such as water quality and livestock health and welfare. Eligibility fulfillment rules in Pillar I are associated with the use of land for permanent grassland, and arable and permanent crops. The requisites for farmers to receive payments from Pillar II are established by each Member State based on their own interests from a productive and environmental point of view. Pillar II is composed of Regional and National Rural Development Programs that promote the environment but also the livelihood of farmers. This paper aims to analyse and explain the promotion of agroforestry practices within Cross-compliance, Pillar I, and Pillar II of the CAP at the EU level for the period 2014–2020.

Materials and methods

The analysis carried out in this paper is based on a literature review of the main CAP legislation framework for Pillar I (Regulation 1307/2013) (EU 2013a) and Pillar II (Regulation 1305/2013) (EU 2013b), as

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well as the accompanying and transposed legislation, such as Delegated Acts and 88 out of the 118 Rural Development Programs currently existing in the CAP for the period 2014–2020. Different documents and reports presented by the European Commission in the Civil Dialogue Groups and in the European Network for Rural Development from the European Commission web page were also evaluated thanks to the participation of the European Agroforestry Federation (EURAF, www.agroforestry.eu) in the meetings.

The paper analyses how the presence and management of woody vegetation is promoted within the current European CAP framework (period 2014–2020) extending beyond the agroforestry specific measure in Pillar II included in the CAP in 2007. Agroforestry promotion was evaluated in the different sections of the CAP whose fulfillment by farmers is required, such as (i) cross-compliance, whose rules have to be adopted as a prerequisite to get payments linked to Pillar I or Pillar II; (ii) direct payments that include eligibility and Greening measures within the norms required to receive support from Pillar I; and (iii) Pillar II. In all these sections, the CAP allows the selection of activities for implementation by the National Programs, which in turn develop strategies linked to the Partnership Agreement. The selected options may vary or are expanded as the CAP is implemented within a specific commitment period. The evaluation was carried with the available information up to year 2017.

Results

Agroforestry definition

Within the EU, Article 23 of Regulation 1305/2013 (EU 2013b) defines agroforestry systems as "land-use systems in which trees are grown in combination with agriculture on the same land". However, woody perennials are considered by the European Commission in the application of Regulation 1305/2017, where Measure 8.2 (EU 2014a, b) defines agroforestry on agricultural land in the following terms: "Agroforestry means land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same parcel or land management unit without the intention to establish a remaining forest stand. The trees may be arranged as single stems, in rows, or in groups, while grazing may also take place inside parcels (silvoarable agroforestry, silvopastoralism, grazed or intercropped orchards) or on the limits between parcels (hedges, tree lines)". The EU currently indicates that arable land, and therefore agroforestry on such land, is not be eligible for direct payments if it contains more than 100 trees/ha, as established by Regulation 640/2014 (Mosquera-Losada et al. 2016b), although it allows Member States to select tree densities below this maximum if local practices are implemented on permanent grassland. The focus on woody perennials was also part of the definition for agroforestry as used in the EU-sponsored AGFORWARD research project that ran from 2014 to 2017 (Burgess et al. 2015) and FAO (2017). ICRAF specifies that the concept of 'trees' is linked to woody perennials (therefore, 'trees and shrubs').

Cross-compliance

Farmers get paid the direct payments and Greening, as well as Pillar II funds, upon fulfilling the Statutory Mandatory Regulations (SMRs) and Good Agricultural and Environment Conditions (GAECs), generally known as Cross-compliance (conditionality). SMRs refer to EU Directives and Regulations linked to public, animal, and plant health, identification and registration of animals, and environmental and animal welfare. Agroforestry is able to directly fulfill the first three measures (nitrate vulnerable zones and biodiversity dealing with birds and habitats) of the SMRs, but the rest may also be improved by sustainable agroforestry practices (e.g. the quality of feed and food).

The GAECs within the period 2014–2020 currently include options related to water and soil and carbon stocks, where agroforestry can play a role as a sustainable agricultural practice as per GAEC 7, linked to the retention of landscape features. Landscape features include woody vegetation such as hedges and trees in line, in groups, or isolated which are directly related to agroforestry practices, among other features such as ponds, terraces, and field margins (Santiago-Freijanes et al. 2018). The agroforestry practices linked to GAEC 7 are of high interest in some countries as they avoid problems related to winds or flooding and enhance the biodiversity.

Table 1 Summary of selected measures to promote agroforestry by countries within the Rural Development Programme (2014–2020)

Measure code and name, and associated article	Name of sub-measure
1. Knowledge transfer and information actions	1.1—Support for vocational training and skill acquisition actions
	1.2—Support for demonstration activities and information actions
2. Advisory services, farm management and farm relief services	2.1—Support to help benefiting from the use of advisory services
	2.3—Support for training of advisors
4. Investment in physical assets	4.1—Support for investments in agricultural holdings
	4.2—Support for investments in processing/marketing and/or development of agricultural products
	4.3—Support for investments in infrastructure related to development, modernisation or adaptation of agriculture and forestry
	4.4—Support for non-productive investments linked to the achievement of agri-environment-climate
5. Restoring agricultural production potential…and introduction of prevention actions	5.1—Support for investments in preventive actions aimed at reducing the consequences of probable natural disasters, adverse climatic events and catastrophic events
6. Farm and business development	6.1—Business start up aid for young farmers
	6.3—Business start-up aid for development of small farms
7. Basic services and village renewal in rural areas	7.4—Support for investments in the setting-up, improvement or expansion of local basic services for the rural population including leisure and culture, and the related infrastructure
	7.6—Support for studies/investments associated with the maintenance, restoration and upgrading of the cultural and natural heritage of villages, rural landscapes and high nature value sites including related socio-economic aspects, as well as environmental awareness actions
8. Investments in forest area development and improvements of the viability of forests	8.1—Support for afforestation/creation of woodland
	8.2—Support for establishment and maintenance of agroforestry systems
	8.3—Support for prevention of damage to forests from forest fires and natural disasters and catastrophic events
	8.4—Support for restoration of damage to forests from forest fires and natural disasters and catastrophic events
	8.5—Support for investments improving the resilience and environmental value of forest ecosystems
	8.6—Support for investments in forestry technologies and in processing, mobilising and marketing of forest products
9. Setting up of producer groups and organisations	9.1—Setting up of producer groups and organisations in the agriculture and forestry sectors
10. Agri-environment climate	10.1—Payment for agri-environment-climate commitments
11. Organic farming	11.1—Payment to convert to organic farming practices and methods
	11.2—Payment to maintain organic farming practices and methods
12. Natura 2000 and water framework directive payments	12.1—Compensatory payments for the arable land in NATURA 2000
13. Payments to areas facing natural or other specific constraints	13.2—Compensation payment for other areas facing significant constraints
15. Forest-environmental and climate services and forest conservation	15.1—Payment for forest-environmental and climate commitments
16. Co-operation	16.5—Support for joint action undertaken with a view to mitigating or adapting to climate change, and for joint approaches to environmental projects and ongoing environmental practices

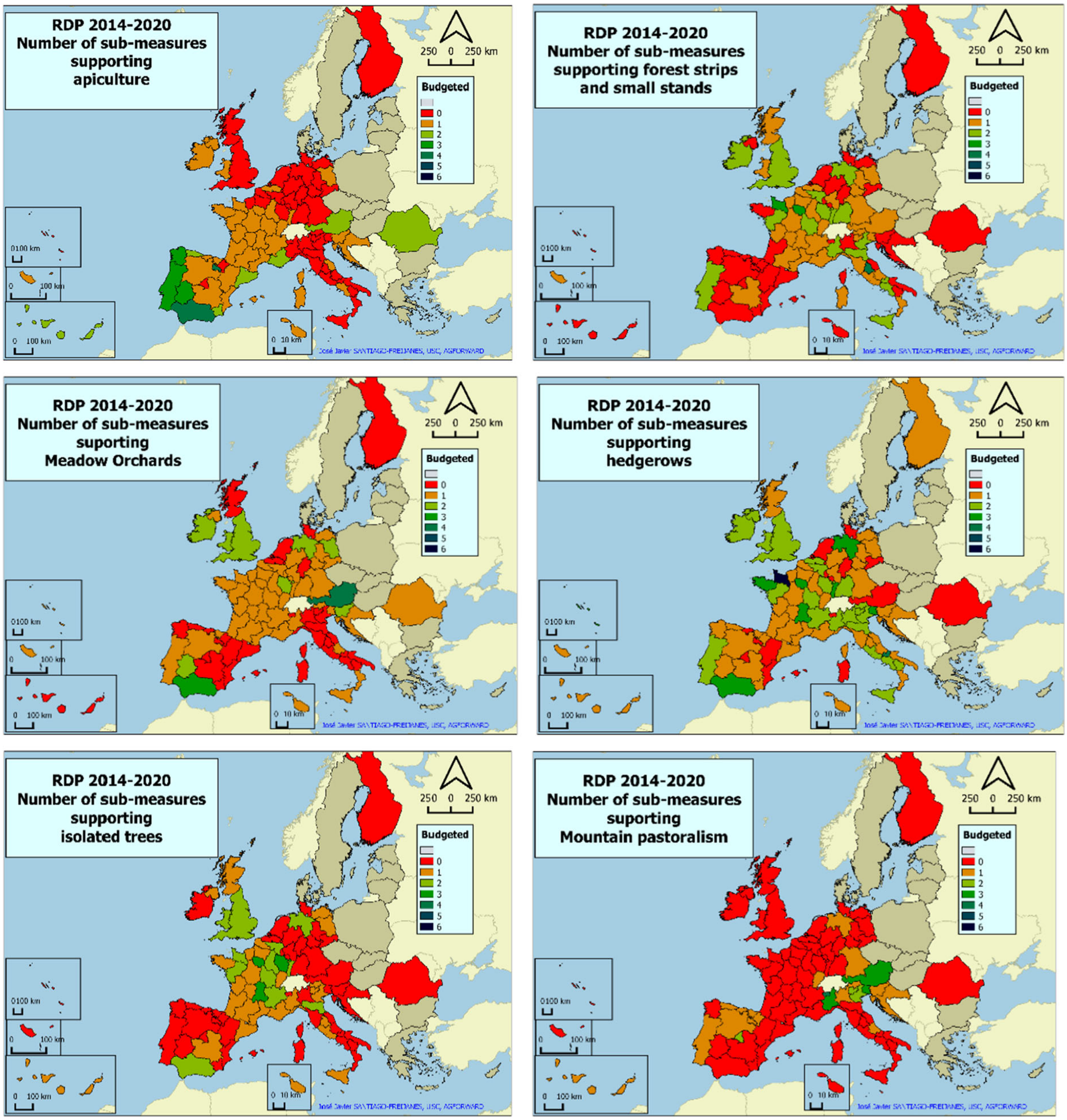

Fig. 1 Number of submeasures of rural development programs promotion agroforestry dealing with apiculture, forest strips and small stands, meadow orchards, hedgerows, isolated trees and mountain pastoralism

Pillar I

Direct payments

CAP establishes three different types of land for the evaluation of their suitability to receive basic payments and Greening through eligibility: arable land, permanent grassland or permanent pasture, and permanent crops.

Arable lands The eligibility of arable lands is limited by the Delegate Act 640/2014 (EU 2014a) to those lands with a tree density below 100 trees/ha. This specific constraint makes it difficult for farmers to introduce trees on their arable land, in particular when they own small plots. The conditions for those trees, defined as isolated trees, are provided in the Delegated Act 639/2014 (EU 2014b) as those with a minimum crown diameter of 4 m, which means a tree cover of 1256 m^2/ha (12.56%) when considering the 100 trees/ha rule. If trees are grouped, the maximum area allowed for woody vegetation is even lower, as the CAP allows the 10% of the hectare (1000 m^2/ha) to get paid. Regarding hedges or hedgerows, the regulation protects those already existing with a width of up to 10 m (Regulation Act 639/2014 (EU 2014b)), but only those with a 2-m width can be claimed as eligible land for payment even if the Member State protects wider hedges (DEFRA 1997).

Permanent grassland or permanent pasture Following the definition given in Regulation 1307/2013 (EU 2013a), permanent grassland or permanent pasture refers to "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 5 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 (ELPs) where grasses and other herbaceous forage are traditionally not predominant in grazing areas". This can therefore include agroforestry as woody vegetation is admitted, for which no predominant herbaceous grasslands can claim full payment if ELPs are selected by the European Member States. Countries that have active ELPs, and therefore payments for non-predominant herbaceous permanent grasslands, are Germany, Spain, Sweden, Greece, France, Hungary, Italy, Cyprus, Portugal, and United Kingdom. However, all non-predominant herbaceous permanent grasslands may be able to claim full payment if grazed thanks to the implementation of the OMNIBUS Regulation in 2018 (European Council 2017).

Permanent crops Permanent crops are defined by the Commission as non-rotational crops other than permanent grassland that occupy the land for 5 years or more and yield repeated harvests, including nurseries and short rotation coppice. For permanent crops, the tree densities set for arable land eligibility do not apply and combinations with crops are allowed. If fruit trees are combined with grazing, this type of land exploits gaps in the silvopasture concept and again, no restrictions on the fruit tree density apply. Permanent crops are those listed in Annex 1 of Regulation 1308/2013, including apple, pear, apricot, peach, nectarines, orange, small citrus, lemon, and olive trees, as well as vineyards for table production as the woody component.

Greening Greening refers to payments for agricultural practices beneficial for the climate and environment, which, as part of Pillar I payments, represent 30% of the direct payment value received by farmers. Greening, as occurs with cross-compliance, includes landscape features as an option for farmers to fulfill its requirements, but also gives the option of choosing agroforestry. At least one type of landscape feature has been initially selected by 24 Member States; however, this does not imply that trees in line, copses, or isolated trees have been selected, which hampers the evaluation of the impact of the Greening measure. This is because landscape features include other options, such as ponds, terraces, and field margins that are not related to woody vegetation. Moreover, even if countries have made an initial selection, they may not activate it during CAP implementation.

Unfortunately, Greening only affects 40% of the direct payment beneficiaries in Europe, mainly due to the small size of the farms, which receive Greening payments per se. The percentage of the total agricultural area subjected to at least one Greening obligation (crop rotation, permanent grassland preservation, and Ecological Focus Areas) is lower in Southern (Greece, Italy, Malta, or Portugal) than in Northern European countries such as Germany or Latvia. The most selected option of Ecological Focus Areas (EFAs) by the EU Member States is nitrogen-fixing crops (35–46%), followed by catch crops (15–27%), and fallow land (21–35%), which represent 94% of the area fulfilling the EFAs requirements. The selection of any of these three options, among others including agroforestry, is likely due to them being the easiest to implement by farmers. Agroforestry has not been implemented yet and landscape features are only used in around 4.34% of the land claiming Greening support. A greater diversification of the farmers'

EFA choices is expected in the forthcoming years and, hopefully, woody vegetation will be more widely used.

Pillar II

Table 1 shows the measures promoting the woody component in agricultural land and the agricultural activity linked to the woody component in the evaluated rural development programs of the EU, while Fig. 1 presents the number of measures linked to agroforestry implemented in the evaluated EU regions. Most of the CAP 2014–2020 programs were approved during 2015, and thus had only been partially implemented in 2016. To carry out this evaluation, we read the 88 Rural Development Programs (RDPs) implemented in Europe and organised them based on the activities they finance that are linked to agroforestry practices (silvopasture, silvoarable, forest farming, riparian buffer strips, and homegardens). The selected activities include those associated with forest farming agroforestry practices (apiculture), those increasing the woody vegetation across Europe (forest strips and small stands, hedgerows, isolated trees), those dealing with permanent crops of fruit trees (orchards) and, finally, those related to silvopasture (forest understory grazing and mountain silvopastoralism). Twenty-three measures have been established in Europe that can be associated with agroforestry within the RDPs framework, but they do not mention agroforestry or any of its practices in a specific way, with the exception of Measure 8.2 out of all the RDPs measures of the CAP 2014–2020. From those, the measure that mostly supports agroforestry is the agri-environment measure (Measure 10.1). Hedgerow (woody component) establishment and management is the most extensively promoted measure linked to agricultural land out of the vast number of measures used across Europe, while meadow orchards have been implemented in most regions by one single measure. The specific agroforestry Measure 8.2 was intended for use in only 33 out of the 88 evaluated regions, a number that will probably increase in the forthcoming years. In the first year, only five RDPs implemented the measure out of the 16 that activated it, mainly through activities related to the establishment and management of forest strips, small stands, hedgerows, and forest grazing.

Discussion

Understanding the impact of the CAP and specifically of agroforestry on European lands is difficult due to several reasons, such as (a) the capacity of countries to choose between different options within the CAP, (b) the variety of options regarding the implementation period, which is typically 7 years, (c) the different environmental and socioeconomic situation of the Member States, and (d) the varying number of EU countries implementing the CAP, which has increased in the last years, affording different degrees of adaptation to said policy. The selection of the CAP alternative measures by each Member State delays usually the start of the CAP implementation by 1 or 2 years. Member States have to construct their own CAP based on the EU CAP framework and choose among the different alternatives in order to adapt the CAP to their own requirements and environments, which is a really important aspect for agricultural sustainability. Furthermore, accountability as well as modification of the CAP rules is always complicated. Moreover, the CAP selection may be modified by Member States during the commitment period, and it is usually reviewed and strongly modified at mid-term with important changes, making the evaluation of the global period extremely difficult. For example, the implementation of Pillar I of the 2014–2020 CAP started at the beginning of 2015, with an extension of the CAP 2007–2013 in 2014, while most RDPs set up their initial choices at the end of 2016, after which farmers could start to meet the requirements to receive support.

Regarding the difficulties agroforestry practices present for promotion at the European scale, several deserve to be mentioned in particular. The FAO (2015) define agroforestry as "a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals". In North America, AFTA (2016) defines agroforestry as "an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock", and USDA (2017) "Agroforestry is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits". The inclusion of 'woody perennials' in the definition of agroforestry in the current CAP (2014–2020) compared to the previous period (CAP 2007–2013), rather than exclusively 'trees', facilitates the sustainability and adaptation of farming systems to the existing different environments in the EU countries in the form of shrubs owing to their woody perennial nature, providing many of the same productive, environmental, and/or social benefits of trees (Mosquera-Losada et al. 2006; Rigueiro-Rodríguez et al. 2009). Moreover, tree definitions vary across countries, and trees can also be cultivated in shrub form while providing the same environmental and social benefits (Mosquera-Losada et al. 2016a).

The current CAP definition of agroforestry applied in Measure 8.2 is adequate, but we argue that the inclusion of a two-layer concept can help to avoid confusion, for example in the case of using fruit trees when the crop is on the tree. Thus, the AGFORWARD project has proposed the following definition: "the deliberate integration of woody vegetation (trees and/or shrubs) as an upper storey on land with pasture (consumed by animals) or an agricultural crop in the lower storey. The woody species can be evenly or unevenly distributed or occur on the border of plots. The woody species can deliver forestry or agricultural products and other ecosystem services (i.e. provisioning, regulating or cultural)" (Mosquera-Losada et al. 2017). Moreover, difficulties exist to clearly identify the different types of agroforestry practices (silvopasture; silvoarable; hedgerows, windbreaks and riparian buffer strips; forest farming, and home gardens) within the Pillar I regulation description, which are typically referred to by local names (e.g. grazed orchards, wood pastures, dehesa, montado, parklands, hedges) but not clearly identified as agroforestry.

Den Herder et al. (2017) and Mosquera-Losada et al. (2016c) which considered exclusively the tree components (excluding shrubs) and woody components (trees + shrubs), respectively, are the first systematic studies to identify the extent and location of agroforestry use and practices in Europe. However due to the lack of data, researchers are not currently able to identify which of these agroforestry practices are linked to CAP payments. The first step to improve the agroforestry policy in Europe is to identify the land where it is applied and how the policy modifies its implementation to create tailor-made agroforestry practice measures according to the needs of specific regions and the ecosystem services they should deliver. Cross-compliance deals with measures for already existing woody components in arable and pasture lands, but not with the enhancement or real promotion of them. The extension of agroforestry practices should be based on a more flexible strategy pursuing the generation of products from woody vegetation while implementing sustainable practices using circular economy and bioeconomy approaches. In general, and when considering the eligibility of an arable land, at present no more than 10% of the arable land is allowed to have an already existing woody component, a number that has been increased from the last CAP 2007–2013, where only a 5% was allowed. However, these rules are still not enough to ensure the productivity and resilience of European arable systems since the tree density does not correlate with the concept of 'mature tree' and most Member States take this density as a limit for any new tree plantation in the European Union. Crown diameters of over 4 m can be considered in most cases mature trees, and trees with diameters smaller than 4 m are not protected even if they are essential to ensure the long term sustainability of isolated trees. The 50 and 100 trees/ha limit given for arable land in the previous (2007–2013) and current (2014–2020) policies, respectively, have caused the destruction of trees, mostly in small plots of farms, in both already land receiving Pillar I payments and on land that farmers are intending to include for future CAP support. Hedgerows larger than 2 m are not generally considered eligible by the EU, even if they are protected, which makes farmers associate them with a reduction of the CAP support, despite the ecosystem services they deliver, and farmers may reduce their size if not destroy them all together. By contrast, alley cropping or silvoarable practices with short rotation coppices are allowed and fully eligible in the current CAP, but they are not promoted or even specifically mentioned. The woody vegetation of permanent pasture has been protected to some extent in those countries where ELPs are applied. However, some countries have decided not to make eligible pastures dominated by woody vegetation by not widening the ELP options, limiting the positive effect that woody vegetation could have for animal feeding during the drought period of the summer. This may change with the implementation of the OMNIBUS Regulation (European Council) in 2018.

Another aspect that undermines the use of woody vegetation in the CAP is that it does not consider the form and the function of that vegetation; instead the assumption is that the reduction in agricultural activity is solely dependent on the tree density. The tree density criterion has at least three main drawbacks. The first one is that the limiting factor for radiation to reach the understory is not the tree density but the tree coverage, which can nowadays be easily measured using satellite images but that is not considered by the CAP. The second drawback is related to the general assumption that the reduction of radiation necessarily reduces the understory production. In practice, some crops adapt and are more efficient under shade conditions, even increasing their productivity (i.e. the production of the active principle rosmarinic acid extracted from *Melisa officinalis* L. is increased in the shade because its maximum productivity and quality is linked to the flowering period, which is delayed in the shade, therefore increasing the active principle production per unit of land). In this regard, genetic selection of crop varieties able to remain productive under shade conditions should be developed, as most varieties already existing in the market have been selected for open conditions. The third drawback of the tree density criterion is the lack of a link between the tree density and the temporal dimension. In some areas, such as the dehesa in Spain, the presence of trees in a plot extends the growing season during droughts and extreme heat, and this mitigates the impact of the reduction in solar radiation (García de Jalón et al. 2018). This is important for the adaptation of agricultural systems to climate change (Sciences Vie 2015).

The current permanent pasture definition indeed recognises all types of permanent grasslands across European biogeographic regions better than the previous CAP, in which it was only associated with herbaceous grasslands. Thanks to the inclusion of the concepts of “self-seeded” (annual herbaceous species) and “grasses and other herbaceous forage traditionally not predominant in grazing areas”, ecological traits linked to species evolution strategies to survive deficient periods (summer) or disturbances (i.e. heavy rains and floods) are included, making the ecosystems more resilient to droughts and heavy rainfall, and able to avoid erosion. However, when a Member State decides to apply a pro-rata system (meaning that the surface of the woody component in permanent grassland is discounted for farm payments), it is applied to all permanent grassland parcels of the Member State or region territory with scattered ineligible features. This choice means that previously ineligible areas smaller than 1000 m^2 are now eligible; unfortunately, this is applied at the parcel level (not per hectare) and therefore the eligibility depends on the parcel size. Farms with large parcels, even those extending several hectares, are only allowed to have 1000 m^2 of woody vegetation. Another problem for agroforestry is the interpretation of the concept of ‘grazable trees’ in permanent grassland. As the EU (2015) indicates, ‘grazable trees’ on permanent grasslands, which are considered part of the eligible area, should not be accounted for when assessing whether the parcel is below or above the maximum tree density. However, the concept of ‘grazable trees’ for the European Commission refers to those features ‘that can be grazed’ and should be actually directly accessible to farm animals for grazing of their full area. This implies that the animals must access the food directly from the trees, rendering ineligible and therefore not counting those trees that have been planted in a plot to provide fruit to animals during the fruit drop season (i.e. *Quercus ilex* in dehesa systems).

Regarding Pillar II, most regions of Europe have activated the promotion of new and/or adequate management of hedgerows and isolated trees with at least one measure. It is important to highlight that the most popular rural development measure (Measure 10.1), the so-called Agri-environment climate commitments (AECMs), recognises the role of woody vegetation in Europe for environmental improvement and the reduction of negative climate change impacts. The lack of recognition of agroforestry in different measures of the CAP, even though the woody component is somehow promoted, reduces the impact of agroforestry practices, since the connection between the crop or pasture and the tree to improve the productivity and the selection of best species or varieties of both components to achieve enhanced productivity in a specific land is not pursued. The visibility of agroforestry should be clear, mostly for the accomplishment of Decision 529/2013 (EU 2013c) regarding the mitigation and adaptation to climate change. However, the specific agroforestry measure (Measure 8.2) has had a low degree of implementation in most European Union regions. Some of the justifications for this fact are: (a) the implementation of agroforestry practices under Measure 8.2 may contribute to the loss of direct payments for specific plots (Mosquera-Losada et al. 2016c), thus stopping farmers from applying them due to the lack of an adequate link between Pillar I and Pillar II; (b) the lack of knowledge on how to better integrate the woody and agricultural components to increase productivity; (c) the lack of a market for the woody or agricultural components perhaps linked to an 'agroforestry label', allowing farmers to obtain benefits from such a more sustainable use of the land; and (d) the lack of payment to farmers for ecosystem services or environmental results.

Nowadays, the EU is aware of the huge existing gap between knowledge and implementation, and has thus created European Innovation Partnerships as a new horizontal approach within the RDPs. A large amount of money has been allocated to operational groups who can undertake different activities where farmers can discuss and develop sustainable practices and within these agroforestry can play an important role. Moreover, the Commission also supports the creation of transnational Focus Groups, where researchers and practitioners are able to discuss specific subjects of interest to the Operational Groups. During 2017, the European Agroforestry Federation supported the Agroforestry Focus Group by providing information, future research directions, and identifying problems that need to be solved to increase the extent and recognition of agroforestry in Europe (Agroforestry Focus Group 2017).

Conclusions

There is clear recognition of the woody component within the CAP but there is minimal overall appreciation of agroforestry. Such a lack of recognition is undermining the flexibility of farmers to pursue the best combinations between the woody component and the agricultural activity from the understory at a range of spatial and temporal scales. We strongly recommend the recognition of agroforestry and agroforestry practices as such through the whole CAP and agroforestry practices that provide wider environmental and social benefit should receive full Pillar I payments on agricultural lands.

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