AGFORWARD
Agroforestry for Europe

Predicting the impact of the widespread uptake of agroforestry on ecosystems and farm profitability

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Contents

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1 Context

The AGFORWARD research project (January 2014 - December 2017), funded by the European Commission, has promoted agroforestry practices in Europe that will advance sustainable rural development. The project had four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This Deliverable Report 7.22 contributes to the third objective as it evaluates the effect of a greater uptake of agroforestry. The deliverable reports studies that test the impacts of an uptake of agroforestry on economic benefits at the farm scale and ecosystem service delivery at the European scale. We also tested if the negative environmental costs created by agriculture can be ameliorated by the greater implementation of agroforestry. In addition, we studied if livestock agroforestry in southern Mediterranean countries could help to reduce fire risk. The deliverable has been produced in the form of four papers that will be submitted to scientific journals. Characteristics of study sites, agroforestry systems and related ecosystem services in the four studies are described in Table 1.

The draft versions of the papers have been submitted to the European Commission and they will be added to an updated version of this deliverable when they are published. The current working titles and working authorship of the papers are as follows:

Paper 1 focussed on European assessment:
Kay S, Roces-Díaz J, Crous-Duran J, Giannitsopoulos M, Graves A, den Herder M, Moreno G, Mosquera-Losada MR, Pantera A, Palma JHN, Rolo V, Szerencsits E, Herzog F. What agroforestry can do to help reaching future goals of European Common Agricultural Policy?

Paper 2 focussed on economic assessment:
Giannitsopoulos ML, Graves AR, Burgess PJ, Crous Duran J, Palma J, Moreno G, Kay S, Garcia De Jalon S, Herzog F. Economic comparison of arable, agroforestry and tree-only systems in three European countries at a plot scale.

Paper 3 focused on environmental costs:
Giannitsopoulos ML, Graves AR, Burgess PJ, Crous Duran J, Palma J, Moreno G, Kay S, Garcia De Jalon S, Herzog F. How agroforestry can compensate environmental costs of arable farming in Europe.

Paper 4 focused on forest fire impacts:
Damianidis C, Santiago Freijanes JJ, den Herder M, Pantera A, Burgess PJ, Mosquera Losada MR, Graves A, Papadopoulos A, Pisanelli A, Camilli F, Palma J. Agroforestry as a measure to reduce forest fires in the Mediterranean areas.

Table 1. Characteristics of study areas, studied agroforestry systems and related ecosystem services in the four studies

Author	**Kay et al.**	**Giannitsopoulos et al. A**	**Giannitsopoulos et al. B**	**Damianidis et al.**
Working title	What agroforestry can do to help reaching future goals of the European Common Agricultural Policy?	Economic comparison of arable, agroforestry and tree-only systems in three European countries at a plot scale	How agroforestry can compensate environmental costs of arable farming in Europe	Agroforestry as a measure to reduce forest fires in the Mediterranean areas
Geographical area considered	Europe	Switzerland, Spain, United Kingdom	Switzerland, Spain, United Kingdom	Cyprus, France, Greece, Italy, Portugal, Spain
System considered	Agrosilvopastoral	Cherry orchards, dehesa wood pastures, poplar plantation	Cherry orchards, dehesa wood pastures, poplar plantation	Silvopastoral
Form of study		Plot-scale analysis in the three case study countries	Regional-scale analysis in the three case study countries	
Approach	Bio-physical	Bio-physical and economic	Bio-physical and economic	Bio-physical
Method	GIS analysis of land cover and ecosystem services	Yield-SAFE bio-physical model to simulate yearly crop yield, tree growth, carbon content and soil erosion by water. Farm-SAFE to carry out the economic analysis	Yield-SAFE bio-physical model to simulate yearly crop yield, tree growth, carbon content and soil erosion by water. Farm-SAFE to carry out the economic analysis	GIS analysis of land cover and European fire data
Spatial scale (site, local, regional)	Europe	Plot-scale	Regional	Regional
Ecosystem service category assessed	Regulating	Provisioning, Regulating	Provisioning, regulating	Provisioning, regulating
Ecosystem service(s) assessed	Soil erosion, carbon storage, nutrient cycling, climate regulation, soil biodiversity, pest control, pollinators	Climate regulation, cereal production, livestock production, firewood production, fibre production, water quality regulation	Climate regulation, cereal production, livestock production, firewood production, fibre production, water quality regulation	Climate regulation, forest fire prevention

Table 1(continued). Characteristics of study areas, studied agroforestry systems and related ecosystem services in the four studies

Author	Kay et al.	Giannitsopoulos et al. A	Giannitsopoulos et al. B	Damianidis et al.
Data handling process (qualitative, quantitative)	Quantitative (statistical analysis on spatial database)	Quantitative (daily time-step dynamic model developed in MSExcel)	Quantitative (daily time-step dynamic model developed in MSExcel)	Quantitative (statistical and GIS analysis)
Mapping (y/n)	Yes	No	No	Yes
Time requirement (high, medium, low degree)	High (data processing and spatial analysis of environmental GIS data layers)	High (Economic analysis, dynamic model developed in MSExcel, Sensitivity analysis)	High (Economic analysis, dynamic model developed in MSExcel)	High (data processing of LUCAS and forest fire data and spatial analysis)
Key conclusion(s)/insights	About half of the European farmland had one or more environmental deficits. In these areas, agroforestry can mitigate environmental problems and in the implementation of new agroforestry systems would be very beneficial in these areas.	The value of the provisioning ecosystem services of forestry and agroforestry was lower than the arable. However, trees generally, increased the equivalent annual value (€ ha^{-1} y^{-1}) when including current prices of the environmental externalities (€ $unit^{-1}$). The reported equivalent annual value included the combined effect of the systems on the provisioning and the regulating ecosystem services. In future work adding other ecosystem services to the model would be beneficial.	Changing arable land by integrating trees can be used to create i.e. carbon-neutral systems when sequestration and tree biomass matches emissions from production of arable systems. Tree-based systems are also effective on reducing other environmental externalities impacts.	Forest fire data from 2008-2017 indicated that agroforestry areas had fewer fire incidents than forest or shrublands providing evidence of the potential of agroforestry to reduce wildfire risk.

2 Description and synthesis of four papers

Agroforestry is the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal production systems to benefit from the resulting ecological and economic interactions (Burgess et al. 2015). There is a large diversity of agroforestry practices including land uses such as silvoarable systems, forest farming, riparian buffer strips, improved fallow, multipurpose trees and silvopasture systems (Mosquera-Losada et al. 2009, den Herder et al. 2017). In the past, agroforestry was a common land use in Europe and many current traditional land-use systems involve agroforestry. However, economic conditions and a drive to produce low cost food decreased the importance of these systems during the twentieth century. Partly due to greater use of mechanisation and agrochemicals, agricultural productivity increased during the 20th century but this has meant that modern agriculture typically relies on high external inputs per hectare.

It is expected that the demands for agricultural production will continue to increase due to population and economic growth (Godfrey et al. 2010). One general perception is that a similar high external input approach as used in the last 40 years can also be used to address the demand for food in the next 50 years by improving productivity using new emerging technologies such as genetic modification, precision farming, smart irrigation systems and robotics. However, many of the smaller farms (86% of the 10.8 million farms in the EU are smaller than 20 hectares (EUROSTAT 2013)) will not have sufficient financial resources to invest in these rather expensive technologies. Because of the widespread negative environmental impacts of modern agriculture, ecological or ecosystem based approaches have emerged that seek to reduce the dependence on large chemical inputs. Agroforestry is one example of such an approach. In recent years agroforestry has regained attention in Europe as a means of maintaining food production and profitability whilst enhancing environmental sustainability. Agroforestry systems provide multiple ecosystem services including the provision of food, feed and fibre to non-commodity outputs, such as climate, water and soil regulation and recreational, aesthetic and cultural heritage values (McAdam et al. 2009, Smith et al. 2013, and Torralba et al. 2016).

The current extent of agroforestry in Europe is about 15 million hectares equivalent to 8.8 percent of the utilized agricultural area (den Herder et al. 2017). Agroforestry is most commonly practiced in southern and south-eastern Europe. It is much less common in the other European regions. Therefore, there would be opportunities for applying agroforestry at a wider scale, especially in those regions where agroforestry is currently not widely practiced. However, even though there are support measures in place, the expansion of existing agroforestry areas and the establishment of new agroforestry systems has remained limited (Martineau et al. 2016). Although farmers are positive about the benefits of agroforestry, they are reluctant to start practicing it mainly because of economic considerations, lack of knowledge, increased complexity of the work, and legal and bureaucratic barriers (Camilli et al. 2017, Garcia de Jalón et al. 2017, Rois-Díaz et al. 2017, Lovrić et al. 2018). In many areas in south and south-eastern Europe there are still genuine ancient wood-pastures which means that there is the 'agroecological setting' for the uptake and continuation of wood-pasturing practices (Hartel et al. 2018). In addition, farmers do value the scattered trees on pastures for their tangible (e.g. shade for livestock) and intangible values (e.g. aesthetic and cultural values)(Hartel et al. 2017). However, these values are not actively promoted by policies and markets. This represents a risk for these systems. It is clear that the willingness and interest among farmers exists, however, to initiate a wider adoption of agroforestry, some additional support actions are needed.

Recent studies have demonstrated that agroforestry has a positive impact on biodiversity and the delivery of ecosystem services (Jose 2009; Torralba et al. 2016). Other studies have demonstrated that agroforestry can also make a positive contribution in mitigating climate change and offer opportunities to adapting our agricultural systems to climate change impacts (Aertsens et al. 2013, Hernández-Morcillo et al. 2018). Studies have shown that agroforestry can increase carbon storage and sequestration, and better absorb excess nutrients compared to conventional agricultural systems (Schoeneberger et al. 2012; López-Díaz et al. 2017). Storms and strong winds, forest fires, flooding events, heavy rains, extreme drought, heath waves, pests and diseases are expected to become more frequent with climate change. Agroforestry can help to adapt to these predicted changes by providing shelter against strong wind and solar radiation; reducing erosion and flooding, reducing fuel loads in forests, and improving the resilience against pests and diseases (Schoeneberger et al. 2012; Moreno et al. 2017).

Assessment of the ecosystem services provided by agroforestry can help to quantify the societal benefits of agroforestry, and this can then help strengthen the political support for agroforestry in the European Union. A demonstration of the potential consequences of agroforestry applied on a wider scale would also be important for policy makers when deciding about agricultural support policies.

This deliverable provides a synthesis of the possible consequences of the uptake of agroforestry by farmers on farm profitability and ecosystems. It consists of four papers focusing on economic and environmental aspects of agroforestry from the farm to the European scale. Some of the evaluations build on the research reported by Roces-Días et al. (2017) and Fagerholm et al. (2018) and the results of 12 European case studies to evaluate the social, economic and environmental impacts of agroforestry. The deliverable summarises the next step of our assessments, as it identifies areas in Europe where agroforestry would be a suitable land use alternative and projects the implications of a wider uptake of agroforestry at the European scale.

Paper 1 is a study by Kay et al. who estimates the potential of some proposed agroforestry systems to mitigate multiple environmental problems based on results from 12 European case study regions. Based on literature and existing cartographic information, areas with potential environmental deficits were identified. This resulted in a series of continental scale maps of ecosystem service deficits. Hereafter, the deficit region maps were overlaid to create a heat map for environmental deficits and to identify priority areas where agroforestry could be implemented to ameliorate environmental deficits. Based on the assessment, areas of grassland result in fewer environmental deficits compared to cropland. Only 2% of the arable areas had no deficits, while in grassland it was around 12%. Half of the grassland area showed deficits in one or two ecosystem services, while 35% of cropland was affected by deficit in more than five ecosystem services. There were some regional differences and the analysis showed that hotspot environmental problem areas (4 or more deficits) included the north-western part of France, Denmark, central Spain, the North (Po region) and the south-west (Sicily) of Italy, and the eastern part of Romania. Although the authors conclude that about half of the European farmland is in “rather good shape”; the other half is not. The study by

Kay et al. provides an indication where agroforestry can mitigate environmental problems and the implementation of agroforestry would be very beneficial in these areas. The authors are planning a follow-up study to estimate the overall benefit of implementing new agroforestry systems in these areas and their contribution to climate change mitigation through enhancing carbon storage in European farmland.

Paper 2 is a study by Giannitsopoulos et al. which models the profitability of arable, agroforestry and forestry systems at plot-scale (1 ha) by using the Farm-SAFE model, in three European countries: United Kingdom, Spain and Switzerland and then also accounts for the environmental externalities. The study assesses the financial (farmer perspective) and economic performance (societal perspective) of the systems whilst also evaluates the environmental externalities by monetarizing their costs and benefits. The studied environmental externalities included: carbon sequestration, nitrogen and phosphorus surplus, and soil erosion. The study identifies the price at which each environmental externality must be set (€ per unit) in order for the annual net benefit of agroforestry or forestry to match the net benefit of an arable system. A sensitivity analysis using current environmental externalities values, derived from Graves et al. (2015), is included to determine how the three systems compare against each other and against the financial baseline.

The initial draft of **paper 3** by Giannitsopoulos et al. compares the profitability and societal value of agroforestry relative to agriculture at a 10,000 ha scale for selected sites in the UK, Spain and Switzerland. In Spain, agroforestry was more profitable than agriculture, assuming no Pillar 1 payments, but agriculture was more profitable than agroforestry when Pillar I payments were included. In Switzerland, the profitability of arable, agroforestry and forestry were very dependent on grants and were not profitable without grants. In this study, the highest net carbon sequestration was observed in forestry systems, due to relatively high tree densities and lower emissions of machine operations and external inputs (Figure 1). In the agroforestry systems, the best net sequestration rates occurred in the UK and Switzerland where fast growing trees were assumed and were planted at a sufficient density to offset the emissions associated with the arable component of the system. In Spain, where a low density of 50 trees ha^{-1} was assumed for holm oak, which is relatively slow growing, the sequestration by the tree component was not sufficient to offset the emissions associated with the arable operations, although the emissions of the agroforestry system are less compared to an arable only scenario.

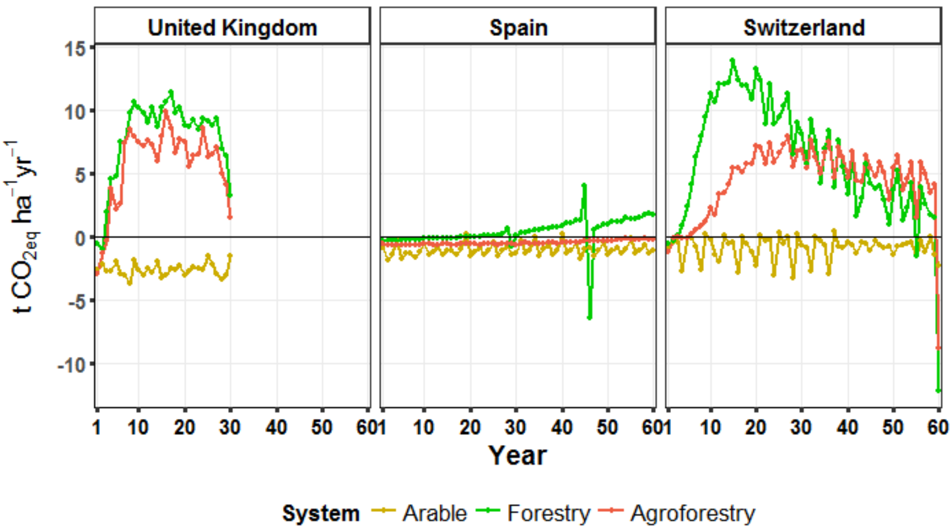

Figure 1. Initial modelled per-hectare outputs of annual net carbon benefit for the arable, agroforestry and forestry systems for UK, Spain and Switzerland over 30, 60 and 60 years which are used to inform a 10,000 ha scale analysis (from Paper 3 by Giannitsopoulos et al.)

Paper 3 also shows that inclusion of the value of environmental externalities such as carbon sequestration, nitrogen surplus, phosphorus surplus and soil erosion tended to increase the economic value of agroforestry and forestry relative to agriculture. The final part of the paper examines how agroforestry could ameliorate the negative environmental costs of arable farming in Spain, Switzerland and the United Kingdom. The study attempts to answer: i) how much arable land (in ha) we have to convert to agroforestry or forestry (by integrating trees) in order to have e.g. a carbon neutral land-use system or a 20% reduction in nitrogen and phosphorus losses or soil erosion, and ii) what would be the impact of this land-use change on economic performance (equivalent annual value; € y^{-1}).

The initial results suggest that in the UK, it would be necessary to convert 11.6% (1157 ha out of 10000 ha) of current arable land to agroforestry to achieve carbon-neutrality as defined in the methodology. In Spain, conversion of arable land to agroforestry resulted in large greenhouse gas emissions savings. However, a 100% carbon-neutral agroforestry landscape was not feasible according to our modelling study. It must be noted however that we simulated a relatively low tree density of 50 trees ha^{-1} in the agroforestry system. With a higher tree density, carbon-neutrality would be more easily achieved. The initial analysis indicates that in Switzerland, a carbon-neutral landscape would be feasible by converting 16.5% of the arable land into agroforestry.

The study demonstrates that a 20% reduction in nitrogen and phosphorus losses could be achieved by converting 12-32% of the arable land to agroforestry in the three case studies. It was calculated that a 20% reduction in soil erosion was harder to achieve and would need a conversion of about 32 to 123 percent of the arable land into agroforestry. Forestry was the most efficient way of minimising soil erosion. In all three countries, the analysis showed that the net financial benefit of crop yields was greatest when the land was 100% covered with arable crops, and introducing trees reduced crop yields. By contrast, the net economic benefit of regulating services was increased by integrating trees. Overall establishing agroforestry or forestry on arable land resulted in higher societal benefits (provisioning plus regulating ecosystem services) than the default option of arable agriculture.

Paper 4 by Damianidis et al. evaluates the potential of agroforestry to reduce forest fire risk in Mediterranean regions. Forest fires are a big risk in Mediterranean countries and catastrophic wild fires present a great threat to societies causing large economic losses and loss of life. Each year, approximately 450 thousand hectares are burnt in just five Mediterranean countries (France, Greece, Italy, Portugal, Spain) (San-Miguel-Ayanz and Camia 2010) and the area is expected to increase in future decades due to climate change (Seidl et al. 2014). Largely unmanaged forests contain high fuel loads increasing the risk of large and rapidly spreading wildfires and large CO_2 emissions. However, forests provide many benefits to society and could make a great contribution to bioeconomy development (Verkerk et al. 2018). In combination with improved forest management, agroforestry can provide multiple environmental benefits, high quality products and benefits to human well-being. The paper by Damianidis et al. examined forest fire risk in areas where agroforestry exists and compared this to the forest fire risk in forest, shrublands and grasslands. Forest fires data from 2008-2017 indicated that agroforestry areas had proportionately fewer fire incidents than shrublands providing evidence of the potential of agroforestry to reduce wildfire risk. Silvopastoralism can reduce the amount of biomass fuel, especially for lower structured shrub and ground-layer vegetation within browsing height. The initial analysis provides evidence that agroforestry can successfully reduce fire risk and support rural communities by adding value to Mediterranean forest resources and improve human well-being.

Overall the four papers demonstrate that a large proportion of European farmland creates negative environmental effects. In these areas, the maintenance of existing agroforestry or implementation of new agroforestry systems can beneficially mitigate environmental problems. If society was able to specify an economic value for the regulating services provided by agroforestry, the combined value of provisioning and regulating services would in most cases be higher than the value of the same services provided by conventional agriculture. For example, agroforestry can contribute to the creation of carbon-neutral agriculture while at the same time reducing other environmental impacts. Last but not least, agroforestry has a great potential to reduce wildfire risk which is especially important in Mediterranean countries in the context of climate change. To conclude the four studies provide evidence that agroforestry can enhance the environment, successfully reduce fires, produce high quality products, and improve well-being and ecosystem service delivery in rural areas.

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5 Annex

The plan is that this annex will eventually include the published papers.