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Review

Scanning agroforestry-based solutions for climate change mitigation and adaptation in Europe

Mónica Hernández-Morcillo[a,*], Paul Burgess[b], Jaconette Mirck[c], Anastasia Pantera[d], Tobias Plieninger[e]

[a] Department of Geosciences and Natural Resource Management, University of Copenhagen, Frederiksberg C, Denmark
[b] School of Water, Energy and Environment, Cranfield University, Cranfield, Bedfordshire, UK
[c] Department of Soil Protection and Recultivation, Brandenburg University of Technology Cottbus, Senftenberg, Germany
[d] Department of Forestry and Natural Environment Management, Technological Educational Institute (TEI) Stereas Elladas, Lamia, Greece
[e] Chair of Social-Ecological Interactions in Agricultural Systems, University of Kassel and University of Göttingen, Germany

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A B S T R A C T

Agroforestry, the integration of trees and shrubs with livestock and/or crops, can make a substantial contribution to mitigating and enabling adaptation to climate change. However, its full potential will only be achieved if the challenges to agroforestry implementation are identified and the most efficient and sustainable solutions are made widely known. Therefore, the aim of this paper is to explore these challenges and to determine the most suitable set of solutions for each challenge that combines local effectiveness with European scale relevance. We performed a two-step "solution scanning" exercise. First, the main challenges to sustainable agroforestry in Europe were identified through 42 participatory workshops with 665 local stakeholders. The solutions to each challenge were scanned and classified into either direct solutions (28) to address climate change or indirect solutions (32) that improve the sustainability of agroforestry. In a second step, the direct solutions were prioritized through expert consultation in terms of their potential benefits for mitigation and adaptation. The most commonly reported barriers were a lack of knowledge and reliable financial support to which the most widely suggested indirect solutions were agroforestry training programmes and the development of safe economic routes. The direct solutions considered as holding the greatest mitigation and adaptation potential were the adoption of practices capable to increase soil organic carbon pools and the implementation of multifunctional hedgerows and windbreaks respectively. Our solution scanning approach can inform the implementation of the European climate strategy in general and to the Common Agricultural Policy in particular by pointing to concrete climate beneficial actions.

1. Introduction

Europe is warming faster than many other parts of the world. Over the past decade, the European land temperature has increased by 0.3 °C more compared to the global average rise since the pre-industrial era (IPCC, 2013). Although all EU Member States are affected by climate change, the impacts will vary across sectors and countries.

Agriculture is particularly dependent on the climate, therefore farming activities will need to adapt, particularly in the southern and south-eastern regions of the EU where the negative effects will be greatest (European Commission, 2015a). At the same time, agriculture releases greenhouse gases (GHG) to the atmosphere. Around 10% of Europe's GHG emissions are derived from agriculture (European Environment Agency, 2012). Consequently, European agriculture will need to both adapt to climate change to enhance resilience and mitigate climate change by reducing its emissions.

Agroforestry has been identified as one of the most promising measures capable to integrate both targets (Martineau et al., 2016). It can be considered a nature-based solution to climate change (NBS) as it is supported by nature and can simultaneously provide multiple environmental, social, and economic benefits (Cohen-Shacham et al., 2016; European Commission, 2015b).

1.1. Agroforestry and climate change

Agroforestry can play a significant role in mitigating the atmospheric accumulation of GHGs while helping farmers adapt to climate change (Sharrow and Ismail, 2004; Lal, 2004; Verchot et al., 2007;

* Corresponding author.
E-mail address: m.hernandezmorcillo@gmail.com (M. Hernández-Morcillo).

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Mosquera-Losada et al., 2008; Aertsens et al., 2013; Mbow et al., 2014; Upson et al., 2016). In particular, it offers important opportunities for creating synergies between both adaptation and mitigation actions (Verchot et al., 2007; Schoeneberger et al., 2012).

Two key beneficial attributes of agroforestry systems in terms of mitigation are direct C storage in trees and soils and the potential to offset immediate GHG emissions (Dixon, 1995). Agroforestry systems are able to store more C than conventional arable systems (Baah-Acheamfour et al., 2015) and have a global technical mitigation potential of 1.1–2.2 Pg C sequestered within terrestrial ecosystems over the next 50 years (IPCC, 2007). In particular, agroforestry practices can deliberately enhance the soil organic carbon (SOC) pool, the only terrestrial pool storing C for millennia (Lorenz and Lal, 2014). Aertsens et al. (2013) estimated a theoretical annual sequestration from agroforestry of 1.56 Pg C in the EU27, if it was introduced on 90 million ha of arable land and 50 million ha of pasture land. However, the proposed system would lead to decreases in agricultural production.

For example, Upson (2014) calculated that a poplar system at 10 m × 6.4 m spacing in the UK would sequester 2.7–2.9 t C/(ha year) in trees, but arable crop production would not be profitable for 12 years after tree planting. A long-term agroforestry system that integrates trees on crop or pasture land and allows agriculture to remain productive over the long-term is likely to sequester C at a lower level. Although the values cited by Aertsens et al. (2013) may be too high, they indicate that there is strong potential for agroforestry practices to be expanded in Europe (Mosquera-Losada et al., 2016), contributing positively to the EU climate change strategy (European Commission, 2013).

Agroforestry can also reduce the negative impacts of climate change and enhance the resilience of European farmers, for example by reducing the effects of extreme weather events. In Spain, an experiment combining short-cycle cereals and late sprouting walnuts demonstrated that partial shade could offer protection from the more frequently occurring spring heat waves that are damaging cereal crops in Mediterranean countries (Arenas-Corraliza et al., 2016). Additionally, agroforestry systems could provide greater stability through more diversified enterprises with different sources of income and products, providing a buffer against yield fluctuations caused by unstable climate or extreme weather events. For example, silvopastoral systems allow farmers to establish a tree crop (which can, for example, provide timber and fuelwood) whilst maintaining forage and livestock production (Méndez et al., 2010; Cubbage et al., 2012). A summary of agroforestry benefits for climate change is presented in Table 1.

Besides, agroforestry can provide diverse ecosystem services (Tsonkova et al., 2014; Fagerholm et al., 2016) such as enhanced nutrient cycling, reduced risks of soil erosion and flooding (Rivest et al., 2013; Carroll et al., 2006), increased biodiversity (Torralba et al., 2016), and integrated pest management and improved resistance to diseases (Bianchi et al., 2006; Beer et al., 1998). Due to their environmental and socio-economic benefits, agroforestry systems represent an important value for society in general and for the agricultural sector in particular (Aertsens et al., 2013).

1.2. Agroforestry in Europe

The European Union has defined agroforestry as “land use systems in which trees are grown in combination with agriculture on the same land” (European Union, 2013a). It has been estimated to cover 15.4 million ha of land in the European Union (EU 27) (den Herder et al., 2017). When adding grazed shrublands (2.7 million ha) and home-gardens (1.8 million ha), the total cover of agroforestry amounts to ca. 20 million ha (Mosquera-Losada et al., 2016). About 90% of this area is linked to silvopastoral practices, a combination of forestry and grazing of domesticated animals. Agroforestry is promoted through the EU Common Agricultural Policy (CAP) Pillar I as one of the choices of the ecological focus area (EFA) greening options (European Union, 2013b). However, this support refers only to the establishment of new agroforestry systems (not to the maintenance of existing ones). Additionally, agroforestry is supported by the CAP Pillar II through the European Rural Development Council Regulations 1698/2005 (art. 44) and 1305/2013 (art.22, art.23), in recognition of its role in reducing C emissions and promoting C sequestration, which would help to fulfill the requirements of the Paris Agreement.

1.3. Realising the climate benefits of agroforestry

Despite its high potential, agroforestry has not yet been adopted on a large scale as a mitigation or adaptation mechanism in most countries of the EU, and its uptake is growing slowly due to several socio-economic and technical challenges (Martineau et al., 2016; García de Jalón et al., 2017). In particular, the high practical experience needed to deal with complex management and the lack of reliable advice and financial support are strong barriers for farmers to implementing agroforestry systems (Martineau et al., 2016). To enable agroforestry in Europe to contribute to climate change, these barriers need to be identified in more detail and overcome. Hence, the aim of this paper is to explore these challenges and to determine the most suitable set of solutions that combines local effectiveness with European scale relevance. In particular, we prioritize a set of potential solutions for mitigation and adaptation to climate change by consulting European agroforestry experts.

2. Methods

To facilitate a comprehensive list of agroforestry-based solutions, we performed a “solution scanning” exercise. Solution scanning is a structured, step-wise methodology to identify a long list of actions, interventions, or approaches that respond to a broad challenge (Sutherland et al., 2014). Such a list can be useful in a broader decision-

Table 1
Agroforestry benefits for mitigation and adaptation to climate change (adapted from Schoeneberger et al., 2012).

Climate change activity	Major climate change functions	Agroforestry functions that support climate change mitigation and adaptation
Mitigation	Sequester carbon	Accumulate C in woody biomass
		Accumulate C in soil
	Reduce GHG emissions	Reduce fossil fuel consumption in equipment
		Reduce CO_2 emissions from farmstead structures
		Reduce N_2O emissions by greater nutrient uptake and reduced N fertilizers
		Reduce CH_4 by enhancing forage quality
Adaptation	Enhance resilience	Maintain quality and quantity of products
		Increase habitat diversity
		Increase structural and functional diversity
		Foster diversified production opportunities
	Reduce threats	Reduce impacts of extreme weather events
		Reduce stress in flora and fauna
		Provide corridors for movements of wildlife