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Evaluating the demand for carbon sequestration in olive grove soils as a strategy toward mitigating climate change

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ABSTRACT

In this paper we present an estimate of the economic value of carbon sequestration in olive grove soils derived from the implementation of different agricultural management systems. Carbon sequestration is considered jointly with other environmental co-benefits, such as enhanced erosion prevention and increased biodiversity. The estimates have been obtained using choice experiments and show that there is a significant demand from society for these environmental services. From a policy perspective, an agri-environmental scheme that delivers the highest level of each environmental service would be valued by society at 121 Euros per hectare. If we focus on carbon sequestration, each ton of CO_2 would be valued at 17 Euros. These results show that there is scope to include agricultural soil carbon sequestration in climate change mitigation strategies and to provide guidance for setting payments for agri-environmental schemes promoting soil management changes.

1. Introduction

The way society views agriculture in the developed world has broadened to include functions beyond the provision of food and fiber, mostly related to territorial and environmental issues. Regarding the latter, the relationship between agriculture and climate change has gained prominence lately both due to adaptation and mitigation issues (Young et al., 2007; Smith et al., 2008). In this sense, agriculture is different to other sectors in that it simultaneously contributes to carbon emissions and acts as a carbon sink. During the 20th century, the former has gained prominence and agriculture-related emissions currently represent approximately 14% of total anthropogenic emissions (FAO, 2006).

Increasing agriculture-related carbon emissions are in line with the more general pattern of ecosystem provision degradation (MEA, 2005) and are related mainly to agricultural area expansion and crop practice intensification (Tilman et al., 2002). However, according to the Intergovernmental Panel on Climate Change (IPCC, 2003), a change in this trend is possible, as modifying agricultural practices, mainly by reducing tillage, could significantly increase soil carbon sequestration by up to 0.3 tons per hectare and year. Moreover, carbon sequestration by agriculture has been found as one of the most cost-effective mitigation options (Antle and McCarl, 2003; MacLeod et al., 2010), in particular soil carbon sequestration (Schneider et al., 2007). Due to these two circumstances, the European Union (EU) is now considering supporting the carbon sink function of some agricultural and forestry activities[1] in order to assure the achievement of the Kyoto Protocol commitments (EC, 2010).

Thus, GHG mitigation by agriculture can be a technically feasible alternative. However, in order to know whether it is an economically viable option, additional research is required. Both supply and demand concerns need to be taken into account for climate change mitigation policies. As far as supply is concerned, the quantity of carbon sequestration in soils has been studied experimentally and we have calculated the potential for sequestration in Andalusian olive groves (section 2). As regards demand, social sciences have used different approaches to estimate it. The literature in this domain includes opinion polls regarding concerns related to climate change (EC, 2008; World Bank, 2010) and stated preference

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[1] Under *Land Use, Land Use Change and Forestry* (LULUCF), the EU-27 reports a net absorption of 410 × 10^6 tCO_2-eq, which accounts for approximately 8% of the EU's total emissions (EC, 2010).

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valuation exercises have focused on the value of carbon sequestration by different agricultural and forestry activities (Shrestha and Alavalapati, 2004; Brey et al., 2007; Glenk and Colombo, 2011a). This study contributes to the valuation literature using an approach similar to that of Glenk and Colombo (2011a).

Our study thus provides an estimation of the value of carbon sequestration by agricultural soils in order to assess whether this mitigation strategy would be economically viable. In doing so, we contribute to the limited literature on the valuation of carbon sequestration in agriculture by increasing the number of estimates available. Moreover, our study does not only provide an additional estimate for the value of CO_2 sequestration in agricultural soils, but also provides two additional contributions. First, it provides a crop-specific estimate (olive groves), which increases the reality of the valuation scenario and provides more specific information for policy design. Second, it enlarges the territorial coverage of estimates to include less developed areas in Europe (Andalusia), while providing an updated estimate for the Spanish context with increased climate change awareness. Moreover, by comparing costs and benefits for a specific soil management program, it provides an assessment of its economic viability.

The rest of the paper is structured as follows; next we present the main characteristics of the olive grove agricultural ecosystem in Andalusia, focusing on its potential as a carbon sink. Section 3 justifies the selection of the valuation technique and reviews its main characteristics together with the experimental design and survey processes, while Section 4 presents the results obtained. The paper ends with some concluding remarks, highlighting the policy implications and potential for further research.

2. Potential of the Andalusian olive groves for climate change mitigation

2.1. Environmental and socioeconomic description of the olive grove ecosystem in Andalusia

The Region of Andalusia is located in southern Spain. Olive groves in Andalusia are a key component of its agricultural ecosystem covering 1.5 million hectares, which represent a third of the region's Utilized Agricultural Area and a sixth of its total area. Analyzing olive groves in Andalusia is also representative of global olive grove production, as one out of every five olive grove hectares in the world are in Andalusia. The economic importance of the olive industry in the region is reflected by the fact that nearly 25% of total farm income comes from this sector (2.4 billion Euros) and that one out of three farm jobs is related to olive growing (90,000 direct jobs), leading to a *de facto* olive monoculture (CAyP, 2008).

Traditionally, olive groves have been a biodiversity-rich habitat providing a clear example of a high nature value farmland. This has been the result of low input intensity management (scarce use of fertilizers and pesticides), presence of old olives trees with semi-natural herbaceous crops throughout most of the year and their location in mixed crop pattern areas (Beaufoy and Cooper, 2009). However this production pattern has changed drastically in most of the olive area over the last few decades, leading to a reduction in their associated ecological benefits. Olive production has become significantly more intense (the so called 'modernization'), combining an extension of the overall surface area, intensive soil management and input use, which keeps the soil bare most of the year. According to several researchers (Beaufoy and Pienkowski, 2000; Gómez-Calero and Giráldez, 2009) this shift in agricultural system management has led to an increase in the negative environmental impacts associated to olive growing, including: i) biodiversity loss due to the extension of monoculture to large areas and the intensive use of agro-chemicals; ii) increase in erosion rates due to expansion toward steep areas and bare soil management; iii) increase in water non-point pollution due to the systematic use of herbicides and fertilizers; and iv) overexploitation of water resources due to the move from rain-fed to irrigated growing.

Notwithstanding these negative effects, every year more than 900,000 tons of CO_2 have been fixed by growing olive trees (CAyP, 2008). However, whether this impact has led to a net reduction in CO_2 cannot be assessed, as the emissions associated with the intensification process remain unknown.

2.2. Management options to improve olive grove carbon sink performance in Andalusia

The first management option that would increase the role of the olive grove ecosystem as a carbon sink is additional fixation by new trees. However, this option is not deemed feasible nowadays, as in the last 15 years the total olive surface area in the region has increased by 15% (230.000 has), leading to a structural price crisis in the sector at international level. However, there are other options that can increase the carbon sink performance of olive groves related mainly to carbon sequestration in soils (Sofo et al., 2005; Nieto et al., 2010). Olive grove soils are poor in organic matter as a result of bare soil management and the burning of pruning debris (Castro et al., 2008; Gómez-Calero et al., 2009). Table 1 shows the different soil management practices currently used in Andalusian olive groves. Over half of the surface area is under tillage; two out of three hectares have bare soils and also half of the surface area burns pruning debris; these being the practices which register the lowest levels of carbon sequestration in soils.

Changing from bare soil management to the use of plant covers in combination with tillage or residual herbicide application, along with the incorporation of shredded pruning debris into the soil, improves soil structure due to an increase in organic matter (Gómez-Calero et al., 2009). Thus, expanding the adoption of these soil management practices would improve the carbon sink capacity of the olive agricultural system. However, these management systems do not only increase the carbon sequestration function of olive groves, but also reduce soil erosion (Gómez-Calero et al., 2009) and increase the biodiversity of the agricultural system (De la Concha et al., 2007).

Table 1
Distribution of olive grove surface area in Andalusia according to soil and pruning debris management options. *Source*: Own elaboration with data from MARM (2009).

Soil and pruning debris management option	Surface (ha)	Percentage (%)
Bare soil with tillage and pruning debris burning ([a]**T + B**)	380,617	26%
Bare soil with tillage and incorporation of shredded pruning debris (**T + S**)	380,617	26%
Bare soil with no tillage and pruning debris burning ([b]**NT + B**)	113,340	8%
Bare soil with no tillage and incorporation of shredded pruning debris (**NT + S**)	113,340	8%
Weed cover crops under herbicide control and pruning debris burning ([c]**CCH + B**)	122,674	8%
Weed cover crops under herbicide control and incorporation of shredded pruning debris (**CCH + S**)	122,674	8%
Weed cover crops under mechanical control and incorporation of shredded pruning debris ([d]**CCM + S**)	245,349	17%
Total	**1,478,611**	**100%**

[a] **Tillage** implies that the soil is tilled several times throughout the year to assure removal of weeds.
[b] **No tillage** implies that weed control is performed with residual herbicides which are applied in October to prevent weed growth.
[c] **Herbicide control** implies that weeds are allowed on the soil until the beginning of spring when they are killed using herbicides.
[d] **Mechanical control** implies that weeds are allowed on the soil until the end of spring when they are mown.