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Review

Meta-analysis on atmospheric carbon capture in Spain through the use of conservation agriculture

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A B S T R A C T

Conservation agriculture (CA) helps to mitigate climate change. Firstly, the modifications introduced by CA on the carbon dynamics in the soil directly result in an increase of the carbon (C) in the soil fraction. Secondly, CA drastically reduces C oxidation processes by diminishing the mechanical manipulation of the soil.

Spain's position in relation to the Kyoto Protocol must be improved, as is one of the European countries in a non-compliance situation. With the aim of providing knowledge about the potential of CA as C sink in Spain, 29 articles on this subject were reviewed. According to 2010 CA uptake, the results demonstrated that conservation practices have the potential to promote the fixation in soil of about 2 Gg year^{-1} more C than traditional tillage (TT) systems. As indicated by Tebrügge (2001), 3.7 Mg of CO_2 are generated from 1 Mg of C through microbial oxidation processes taking place in the ground, meaning that through CA almost 7.5 Gg of CO_2 could be sequestered from the atmosphere every year until the equilibrium is reached.

C fixation was found to be irregular over time. C fixation rates were high in newly implemented systems during the first 10 years, reaching top values of 0.85 Mg ha^{-1} year^{-1} for no-tillage (NT) and 1.54 Mg ha^{-1} year^{-1} for cover crops (CC) implemented in-between perennial tree rows. After those first 10 years, it followed a period of lower but steady growth until equilibrium was reached. Nevertheless, C decreases of 0.16 Mg ha^{-1} year^{-1} in the first 10 years may be expected when practicing minimum tillage (MT). C sequestration rate resulted higher in case farmers do crop rotations in NT and MT rather than monoculture. In woody crops, studies reported higher C fixation values for native species when compared to sowed CC. Also, climate conditions seem to affect C sequestration rate in Spain. Although in NT differences observed between maritime and continental climates are not pronounced, as approximately 25% of the values recorded in both climates are equal, in the case of MT about 75% of maritime climate values result higher than the continental situation.

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1. Introduction

The consequences of the effects of climate change resulting from the uncontrolled emission of greenhouse gases (GHGs) and additional pressure from the international scientific community has required most countries to adopt an international agreement to implement a series of commitments to be fulfilled by the cooperating countries. These commitments, included in the so-called "Kyoto Protocol," establish a limit for the net GHG emissions based on the economic, scientific and technological development of each country (United Nations, 2011). Analysis of the major GHG types indicates that carbon dioxide (CO_2) is the dominant component in terms of absolute weight, generally above 80% overall. In a breakdown by activity sectors, in 2009 agriculture emitted 10.5% GHGs overall. The Kyoto Protocol provides several mechanisms to try to reduce GHGs, among them is the promotion of activities with a C sink effect as a solution to reduce CO_2 concentrations (West and Post, 2002).

The sink effect is any process that can fix atmospheric C. Agriculture and forestry are virtually the only activities that can achieve this effect through photosynthesis and the C incorporation into carbohydrates. Crops capture CO_2 from the atmosphere during photosynthesis by converting C forms associated with soil organic matter (SOM) for microbial decomposition processes (Johnson et al., 2007). Although agriculture is sometimes excluded from environmental regulations, its ability to offset the emissions of GHGs identifies some agricultural activities as key partner in climate policies (Claassen and Morehart, 2009).

Soil management is one of the best tools for climate change mitigation and adaptation (Lal et al., 2011). In fact, agricultural soils occupy about 35% of the global land surface (Betts et al., 2007). CA introduces important changes in the dynamics of soil C sequestration and promotes this process as well (Carbonell-Bojollo et al., 2011). Crop residues left on the soil surface and no mechanical soil disturbance reduce the rate of mulch decomposition and decrease the mineralization of SOM due to reduced air flow, resulting in a lower accessibility of microorganisms and increased soil C. Therefore, the reduction of tillage reduces and slows the decomposition of plant matter, which promotes the storage of CO_2 fixed in the plant as C and returned to the soil as plant debris. Thus, soils have the potential of storing CO_2, thereby helping to mitigate the emission of GHGs generated by other activities (Reeves, 1997). Generally, there are major differences in organic matter (OM) content between NT, CA best agri-environmental approach for arable land, and TT (Paustian et al., 1997). Hence, CA is an alternative that can help reduce GHGs, mainly due to that C-fixation in the soil through an increase of the OM (Nelson et al., 2009) and to the decrease in the intensity of tillage (FAO, 2011).

Spain, as a signatory of the Protocol, has committed to limiting the average annual net emissions of GHGs to a level of a 15% increase over the net emissions recorded in the base year (1990) during 2008–2012. Data presented at the Fifth National Communication of Spain to the UN Framework Convention on Climate Change, published in December 2009 by the Secretariat General for the Prevention of Pollution and Climate Change of the Ministry of Environment, Rural and Marine Affairs (MERMA), showed that the total emissions in 2007 were 53% over the base-year value. CA is recognized as a C sink by the MERMA and the Spanish Office for Climate Change. Indeed, reduced tillage intensity, increased arable hectares under CA, especially NT, and the use of CC were suggested for the establishment of the CO_2 absorption potential throughout Spanish territories.

Reduced tillage trials were started in Spain at the beginning of the eighties with the purpose of introducing simple conservation methods for soil, keeping a protective cover to mitigate erosion stresses, and to save water. Later, farmers detected the advantage of their reduced production costs (González-Sánchez et al., 2010) and several research groups conducted studies to evaluate the benefits of CA systems on the fixation of C.

As the Spanish National Plan for the Allocation of GHG Emissions Rights assumes that emissions may be reduced by 2% due to C sinks, the purpose of the present study is to provide knowledge with a solid scientific base on the potential of CA in Spain in addressing the task of reducing the concentration of CO_2 in the atmosphere through C sequestration by the review of the published works on this subject by different research groups in the Spanish Autonomous Communities of Andalusia, Aragon, Catalonia, Castille-La Mancha, Castille and Leon, Extremadura, Madrid and Navarra (Fig. 1).

2. Materials and methods

For this study, 29 research papers were reviewed, from 20 locations, covering 11 research group papers from various areas of Spain, as listed in Table 1. According to the literature review, the potential for C sequestration in a particular CA practice is not always equal and depends on several factors. Therefore, this study considered the following characteristics:

- Climate of the area;
- Soil type;
- Crop rotation in arable crops.

In many cases the initial values obtained were not directly comparable. Hence, certain simplifications were made in some variables to calculate a single coefficient for each CA practice. These simplifications are described below.

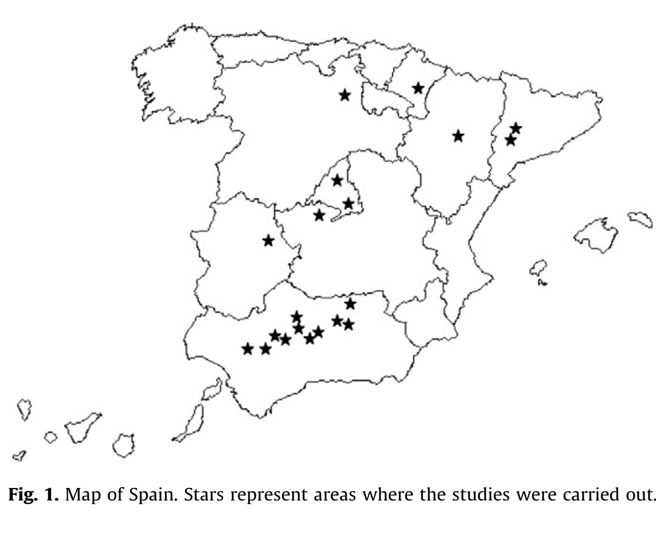

Fig. 1. Map of Spain. Stars represent areas where the studies were carried out.