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Research article

# Management of agricultural soils for greenhouse gas mitigation: Learning from a case study in NE Spain

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ABSTRACT

A portfolio of agricultural practices is now available that can contribute to reaching European mitigation targets. Among them, the management of agricultural soils has a large potential for reducing GHG emissions or sequestering carbon. Many of the practices are based on well tested agronomic and technical know-how, with proven benefits for farmers and the environment. A suite of practices has to be used since none of the practices can provide a unique solution. However, there are limitations in the process of policy development: (a) agricultural activities are based on biological processes and thus, these practices are location specific and climate, soils and crops determine their agronomic potential; (b) since agriculture sustains rural communities, the costs and potential for implementation have also to be regionally evaluated and (c) the aggregated regional potential of the combination of practices has to be defined in order to inform abatement targets. We believe that, when implementing mitigation practices, three questions are important: Are they cost-effective for farmers? Do they reduce GHG emissions? What policies favour their implementation? This study addressed these questions in three sequential steps. First, mapping the use of representative soil management practices in the European regions to provide a spatial context to upscale the local results. Second, using a Marginal Abatement Cost Curve (MACC) in a Mediterranean case study (NE Spain) for ranking soil management practices in terms of their cost-effectiveness. Finally, using a wedge approach of the practices as a complementary tool to link science to mitigation policy. A set of soil management practices was found to be financially attractive for Mediterranean farmers, which in turn could achieve significant abatements (e.g., 1.34 $MtCO_2e$ in the case study region). The quantitative analysis was completed by a discussion of potential farming and policy choices to shape realistic mitigation policy at European regional level.



## 1. Introduction

The European Union (EU) targets for reducing GHG emissions have a clear agricultural contribution, due not only to technical feasibility, but also to potential implementation since the agricultural sector is subject to intervention (EC, 2013b). Therefore, the practices that could be supported by agricultural policy represent a suitable subject for research. However, given the complex interactions of agricultural production with the environment and the sustainability of rural communities, these practices need to be evaluated from agronomic and socioeconomic perspectives.

The collective EU target for all Member States together is to reduce GHG emissions by 20% in 2020 compared to the 1990 baseline. The agriculture sector is part of the Effort Sharing Decision (ESD), which regulates the emission reduction commitments of the sectors that are not part of the Emission Trading System (ETS), i.e. transport, buildings, small industry, agriculture and waste. The ESD targets are Member State specific, e.g. Spain's commitment to reduce GHG emissions in the ESD sector by 10% in 2020 compared to the 2005 baseline (EC, 2013a). In the global effort to reduce GHG

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emissions, the mitigation potential of agriculture can significantly help to meet these emission reduction targets (IPCC, 2014). The GHG emissions reductions to achieve the EU target depend on the quantitative details of mitigation potential of the practices and the agricultural policy that influences farmers' decisions (Smith et al., 2007). Agricultural emissions from livestock and soil and nutrient management contribute to approximately half of the anthropogenic GHG emission (5.0–5.8 $GtCO_2eq/yr$) of the agriculture, forestry, and other land use sector, which in turn represents a quarter of the global GHG emissions ($49 \pm 4.5$ $GtCO_2eq/yr$) in 2010 (IPCC, 2014).

The role of agricultural management to provide Soil Organic Carbon (SOC) sequestration was recognised by the Kyoto Protocol in the United Nations Framework Convention on Climate Change (UNFCCC, 2008). Smith (2012) and the IPCC (2014) indicated that SOC sequestration has a large, cost-effective mitigation potential to meet short to medium term targets for reducing the atmospheric $CO_2$ concentration. The optimistic global estimates are challenged in some local conditions (Lam et al., 2013; Powlson et al., 2014; Derpsch et al., 2014). However, it is clear that smart soil management leads to improved soil health, reduced soil degradation and increased soil carbon, and reduced emissions (Lal, 2013). Therefore soil management changes will benefit soil carbon stocks and, in turn, optimise crop productivity (Ingram et al., 2014; Lal, 2004; Freibahuer 2004; Smith, 2012).

A set of practices with proven benefits to the environment and farmers has been recognised (Lal, 2013; Freibahuer 2004; Smith et al., 2008; Smith, 2012). These practices include, among others: a more efficient use of resources and integrated nutrient management with organic amendments and compost; reduced and no tillage; crop rotations; legumes/improved species mix; growing cover crops; residue management; and land-use change (conversion to grass/trees). However, knowledge on the implementation and cost of specific mitigation practices and technologies at the farm level is limited and fragmented (MacLeod et al., 2010; Smith et al., 2007; Bockel et al., 2012; ICF, 2013). This knowledge is necessary to facilitate government's understanding of potential policy development.

Here, we focus exclusively on practices that contribute to the GHG mitigation targets of the EU and also have clear benefit to soil organic carbon (SOC) content. This choice is guided by four factors: (a) SOC enhancement practices have a proven essential role for global GHG mitigation; (b) SOC enhancement practices are an indicator of long term land productivity and sustainability; (c) improved SOC content requires less nitrogen application, and in turn less $N_2O$ emissions, a major greenhouse gas; (d) improved SOC contributes to soil water improvement by improving the physical soil properties that lead to water retention, therefore this is also an essential adaptation measure to climate change in semi-arid regions linking mitigation and adaptation practices.

The methods used to evaluate the farming choices that contribute to reach a mitigation potential range from purely sociocultural approaches (Morgan et al., 2015) to technical evaluations in field studies (Derpsch et al., 2014). A method that has been proven valuable to communicate science results for mitigation policy is the Marginal Abatement Cost Curve (MACC). The MACCs have been derived to inform policy development for major economic sectors (McKinsey & Company, 2009), for waste reduction strategies (Beaumont and Tinch, 2004; Rehl and Müller, 2013) and for agricultural greenhouse practices in some countries such as United Kingdom (MacLeod et al., 2010; Moran et al., 2011a), Ireland (O'Brien et al., 2014), France (Pellerin et al., 2013) and China (Wang et al., 2014). Further to the MACC approach, Pacala and Socolow (2004) created the concept of stabilisation wedges to clarify how mitigation options could help stabilize atmospheric $CO_2$. This concept has been used widely as it provides a clear-cut way to link science to policy. The stabilisation wedges have been derived for the major carbon-emitting activities by means of decarbonisation of the supply of electricity and fuel, and also from biological carbon sequestration by forest and agricultural management (Pacala and Socolow, 2004; Del Grosso and Cavigelli, 2012).

We believe that, when implementing mitigation practices, three questions are important: Are they cost-effective for farmers? Do they reduce GHG emissions? What policies favour their implementation? This study addressed these questions in three sequential steps. First, mapping soil management practices adoption in the European Union to provide a spatial context to upscale the local results. Second, evaluating a Marginal Abatement Cost Curve (MACC) for ranking mitigation soil and crop practices in a Mediterranean region. Finally, using a wedge approach of the practices as a complementary tool to link science to mitigation policy.

To provide in-depth analysis at a regional level we selected a representative case study in NE Spain that exemplifies semiarid Mediterranean agricultural systems. This intensive agricultural region produces rainfed and irrigated crops (c.a. 89% and 11% respectively); the conventional management undertaken during decades – intensive soil tillage and low crop residue input – have led to soil degradation. Therefore we restrict our attention to strategies that are relevant for semiarid environments and may have linkages to climate adaptation. Here we consider only practices that produce additive effects, in order to calculate the aggregated abatement potential for the entire region as a result of the implementation of all the selected practices simultaneously.

## 2. Methods and data

### 2.1. Overall approach

Our approach to estimate cost-effective management of agricultural soils for greenhouse gas mitigation included three sequential steps. First, we illustrate the current use of crop and soil management with abatement potential in Europe. In this study we evaluated only the practices that require small management changes and that could be easily implemented by farmers without large investments or infrastructure. Second, we estimated the cost-effectiveness and the abatement potential of the selected practices by MACC in a Mediterranean case study (NE Spain) and compared our results with other European regions and sectors outside the agriculture. Third, we built SOC abatement wedges to prioritize practices by abatement potential rather than monetary benefits. The level of spatial aggregation in this study is NUTS2 for both the European and the case study analysis, which is the common classification adopted by the EU to establish basic regions for the application of regional policies (Council regulation (EC) No 1059/2003).

### 2.2. The use of soil organic carbon (SOC) management practices in Europe

To illustrate the use of soil management practices improving SOC flows and stocks in Europe, we developed a database for all EU-27 member states at regional (NUTS2, comparable to province) level. In this study we focused on the extent of adoption of the six soil management practices with abatement potential in Europe which are further analysed in the case study: P1 Cover crops; P2 Minimum tillage; P3 Residue management; P4 Animal manure fertilization; P5 Optimized fertilization; and P6 Crop rotations. We call these SOC management practices. The statistical data on current agricultural land use and application of these practices was