FOREWORD

Greenhouse gas mitigation in the agricultural sector in Spain

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Climate change is a global concern due to its wide implications in several economical, social and biological aspects. During the last two decades, important efforts are being put into practice in order to mitigate greenhouse gas (GHG) emissions from several economical sectors whose activities are exacerbating global warming. According to the last 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), Agriculture is one of the main sectors responsible for the change in atmospheric GHG concentration that has occurred in the last 30 years (IPCC, 2014). The agricultural sector is a main emitter of nitrous oxide (N_2O) and methane (CH_4), two main GHGs. Agricultural soils emit significant amounts of N_2O due to the application of mineral fertilizers and organic manures. At the same time, changes in land use affect soil organic carbon (SOC) stocks whilst enteric fermentation from livestock has been identified as one of the main global sources of CH_4 (Paustian et al., 2006). Agriculture, Forestry and Other Land Use (AFOLU) was responsible for 23% of the total GHG emissions emitted in 2010 (IPCC, 2014). However, the AFOLU sector can also serve as a sink for GHG resulting from other sectors. In particular, carbon (C) accumulated in soils and in plant biomass can remove significant amounts of carbon dioxide (CO_2) from the atmosphere (Conant, 2011).

Spain has the fourth highest land area assigned to agriculture of the European Union (EU) countries. At the same time, livestock production is important particularly pig (*Sus scrofa*), sheep (*Ovis aries*) and poultry (http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database). Thus, agricultural activities in Spain generate significant GHG emissions to the atmosphere. In particular, in 2011 (latest year with available data from the National GHG Inventory), the agricultural sector in Spain emitted 37 Tg of CO_2-eq (MAGRAMA, 2013). This value represented the 10.6% of the total GHGs emitted in the country. Agricultural soils represented the main GHG emitter (about 48% of the total GHGs emitted by the Spanish agricultural sector) followed by enteric fermentation (28%) and manure management (22%) (MAGRAMA, 2013). The reduction of GHG emissions from these three activities, which represent almost the 98% of the total GHG emissions in the Spanish agricultural sector is thus an important challenge.

However, Spain´s diversity in climate, geography and socio-economic circumstances greatly influences the large heterogeneity in agriculture and livestock production systems and thus their associated environmental challenges. Climate and landscape differ significantly across the country. The northern regions have strong influence of humid sea masses from the Atlantic Ocean, the central region is located in an area of high plateau with a temperate continental climate, while the south and west region is predominantly in a Mediterranean climate zone with some areas experiencing semiarid conditions. Within this diversity, crop production systems range from typical dryland cropping systems with cereal fields, such as barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.), as main crops, vineyards (*Vitis vinifera* L.) and olive (*Olea europaea* L.) fields to highly intensified irrigated systems in which orchard plantations, corn (*Zea mays* L.) fields and vegetables prevail. Livestock production ranges from fairly extensive systems in the north based on grazing management to intensified farming practices highly dependent on importation of both forage and grain. Pig production is geographically concentrated in the eastern regions, which brings important environmental concerns related to manure management. In addition, and in part related to the above-mentioned heterogeneity, there is a lack of a national strategy to coordinate all the research efforts focusing on mitigation strategies in the agricultural sector.

Over the last two decades, several Spanish research groups have focused their investigations on determining the factors that control GHG emissions in a variety of sectors and regions in Spain and have designed management mitigation strategies concerned with soils and livestock. Furthermore, research concerned with estimating and maximizing GHG sinks in soils and forest biomass has gained importance over the last decade. In Spanish agroecosystems, historical management has exacerbated soil C loss. Historically, practices such as intensive tillage and long fallowing have depleted soil organic C resulting in an excellent opportunity to sequester atmospheric C in soils through the adoption of alternative management practices (Moreno et al., 2010). Regarding forest biomass, Spain is one of the EU countries with largest forestry surface (European Commission, 2013). The forestry sector in Spain is characterised by a large diversity in species composition and management (Ruiz-Benito et al., 2014). Thus, forest management oriented to maximize tree and soil C storage is another promising strategy to offset atmospheric GHG concentration in Spain.

The main drawback that accompanied the research focussed on GHG mitigation in the agricultural, livestock and forestry systems in Spain has been the feeble connection amongst research groups which share similar research interests, let alone those which are involved in distinct disciplines. Examples of the lack of connection amongst the different research groups are the lack of Spanish studies exploring the integration of the different component levels (e.g. soil, plant or animal) into scales larger than the animal or the field level (e.g. farm, landscape or regional), lack of studies integrating the results from different regions in Spain or/and the absence of studies incorporating the biophysical research findings with socio-economic studies.

In November 2011 a group of researchers from different academic institutions and working on a range of GHG mitigation disciplines from the agricultural, livestock and forestry sectors met in Madrid, Spain to discuss potential approaches to address GHG mitigation in these sectors in Spain. The main output of the meeting was the creation of a new scientific network, whose key objective was to integrate, promote and articulate the scientific community that works on topics in relation to GHG mitigation in the Spanish agricultural, livestock and forestry sectors. The network was called Remedia (Red Científica de Mitigación de Emisiones de Gases de Efecto Invernadero en el sector Agroforestal) and was launched in a first workshop held in March 2012 in Bilbao. The first Remedia workshop was attended by 80 participants from across the country representing a wide range of research interests. The success of the first workshop resulted in the organisation of a second Remedia workshop during the following year in Zaragoza in April 2013. 100 participants attended this event and 70 presentations were given divided in four plenary sessions: forestry, livestock, croplands and socio-economical aspects. Besides discussion about the options to mitigate GHGs in the agricultural, livestock and forestry sectors in Spain, this second workshop served to officially create the scientific Remedia Association. A main conclusion from the first Remedia workshop was the necessity to share the papers presented with the larger scientific community in special issues published in specialised journals. Mitigation and adaptation Strategies for Global Change (MITI) was an excellent option to publish the selected papers presented in the second Remedia workshop due to the scope of the journal and the wide topics covered in the workshop.

The papers in this special issue of MITI deal with the following topics:

1. Management strategies to increase C stocks and C conservation

Four studies representing agricultural and forestry systems analysed the impact of management strategies on C sequestration in distinct Spanish conditions. The study of Almagro et al. (2014) aims to quantify the impact of agricultural management in SOC sequestration and soil structure in rainfed orchards systems. Alvarez et al. (2014) estimate C accumulation in Mediterranean mountain forests. They used the CO2Fix model to predict climate and management effects on soil and tree C accrual. Similarly, Ruiz-Peinado et al. (2014) analyse the effect of thinning on C storage in a long-term forest experiment in central Spain. Armas-Herrera et al. (2014) investigate soil C dynamics in volcanic soils of Canary Islands and the potential of these soils to mitigate atmospheric GHG.

A fifth study evaluates C conservation when the solid fraction of pig slurry is managed for composting. In particular, the study of Santos et al. (2014) evaluates different types of bulking agents on the potential C conservation during composting.

2. Management strategies to mitigate non-CO_2 GHG emissions

Three studies are presented at the field and farm scale level, comprising either arable or grassland-based livestock systems and for different agro-climatic areas (Mediterranean and Atlantic) in Spain. The three papers have a very strong focus on the N cycle at the soil-plant (Gallejones et al., 2014; Sanz-Cobeña et al., 2014) and soil-plant-animal (del Prado et al., 2014) systems, aiming at investigating the effect of management on direct N_2O emissions and other N losses leading indirectly to N_2O (e.g. NH_3). Gallejones et al. (2014) introduce a new field-scale model ($SIMS_{NIC}$) to predict monthly nitrogen (N) flows in cropping systems of Northern Spain. Sanz-Cobeña et al. (2014) study the use of urease inhibitors as a strategy to mitigate ammonia (NH_3) volatilization in agricultural soils. The study of del Prado et al. (2014) present a mass balance farm model (NUTGRANJA 2.0) to simulate N losses in typical grassland-based dairy farms and to establish management strategies to mitigate non-CO_2 GHG emissions considering also potential synergies and trade-offs in N losses other than N_2O.

3. Social-economical issues

Two studies analyse the effectiveness of GHG mitigation practices at the whole country scale. The studies cover this topic from the supply-side (Sánchez et al., 2014) and supply *vs* demand-side viewpoint (Lassaletta et al., 2014), which provides a clear picture of the hot spots for most effective action towards the true reduction of GHG from both the Spanish producer and consumer of food.

Sánchez et al. (2014) analyse behavioural, cultural, and policy barriers for implementation of mitigation practices at the farm level in Spanish agricultural areas. The paper of Lassaletta et al. (2014) examines the trends in N_2O production and consumption in the Spanish agricultural sector from 1961-2009 and provides an alternative picture of that shown by conventional production-based GHG national inventories.

The papers presented in this special issue represent only a sample of the investigations that are currently being carried out concerning GHG mitigation in the Spanish agricultural, livestock and forestry sector, but nevertheless give a taste of the research that is being developed in Spain to an international audience.

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