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Valuing the carbon sequestration potential for European agriculture

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ABSTRACT

Purpose: This paper aims at indicating the potential of agricultural measures in sequestering carbon as an option for climate change mitigation. The related value for society is estimated.
Principle results: Agricultural practices like agroforestry, introducing hedges, low and no tillage and cover crops have an important potential to increase carbon sequestration. The total technical potential in the EU-27 is estimated to be 1566 million tonnes CO_2-equivalent per year. This corresponds to 37% of all CO_2-equivalent emissions in the EU in 2007. The introduction of agroforestry is the measure with the highest potential, i.e. 90% of the total potential of the measures studied. Taking account only of the value for climate change mitigation, the introduction of agroforestry is estimated to have a value of 282 euro/ha in 2012 that will gradually increase to 1007 euro/ha in 2030.
Major conclusions: This implies that there is a huge potential which represents an important value for society in general and for the agricultural sector in specific. At the European level, only in the last few years policy makers have recognized the important benefits of agroforestry. In their rural development programmes some European countries now support farmers to introduce agroforestry. But still the current level of support is only a small fraction of the societal value of agroforestry. If this value would be fully recognized by internalizing the positive externality, we expect that agroforestry will be introduced to a very large extent in the next decades, in Europe and the rest of the world, and this will importantly change the rural landscapes.

Introduction

Today, scientists and politicians recognize that climate change presents an important threat and challenge for mankind. The three most important anthropogenic GHG are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Each of these gases contributes differently to climate change, i.e. they have a different Global Warming Potential, which are, for comparability reasons, expressed in CO_2-equivalency (CO_2-eq). 1 tonne CO_2-eq refers to the equivalent Global Warming Potential of 1 tonne CO_2 during 100 years (1 tonne $N_2O \sim 298$ tonnes CO_2-eq and 1 tonne $CH_4 \sim 25$ tonnes CO_2-eq) (Forster et al., 2007). Before the Industrial Revolution the concentration of Greenhouse Gases (GHG) in the atmosphere was 280 ppm CO_2-equivalent (CO_2-eq). In 2005 this was around 430 ppm. If annual emissions will stay at today's rate it will reach 550 ppm by 2050, resulting in at least a 77% chance of a global average temperature rise exceeding 2 °C (IPCC, 2007). The 2 °C increase has been indicated by scientists as the point beyond which the effects of climate change may become catastrophic and irreversible, and will lead to important damage costs for society (Stern, 2006). Consequently, the long term policy objective of European and global climate policies is to prevent temperature increasing by over 2% relative to pre-industrial levels (EC, 2010; UNFCCC, 2011; Stern, 2006).

Current European emission reduction commitments expire at the end of 2012 and are set at 8% below the 1990 base year for the EU-15. For 2020 the EU has made a unilateral commitment to reduce its GHG emissions to 20% below 1990 levels. With current emission reductions of more than 15.5% across the EU-27 (10.7% across EU-15; EEA, 2011a) an additional effort will be needed. The 20% reduction commitment therefore requires sectors participating in the EU Emissions Trading System to jointly reduce emissions by 21% below 2005 levels and non-trading sectors (under the Effort Sharing Decision; ESD) to reduce emissions by 10%. Emissions and removals relating to "Land Use, Land Use Change and Forestry" are not part of the emission figures quoted, but provisions in the ESD require the Commission to propose how they may be included in the future. With net removals of 410 million tonnes CO_2 in 2008 (8% of total greenhouse gas emissions in the EU; JRC, 2010), the "Land Use, Land Use Change and Forestry" sector is an important part of the EU GHG budget. Taking into account that agricultural lands occupy about 40–50% of the Earth's land surface (FAOSTAT, 2006), in this paper we will show that there is a huge potential for climate change abatement by innovative land use measures in the

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agricultural sector. This potential may be an important relief taking into account the huge cost of climate change abatement actions and taking into account that existing and currently planned measures are likely to be insufficient to bring the EU on the pathway to achieving long-term emission reduction objectives, e.g. by 2030 and 2050 (EEA, 2011b). We will show that the potential for carbon sequestration in the agricultural sector has a very high value for society.

A variety of "climate change mitigation options" exists in agriculture. Practices need to be evaluated for individual agricultural systems based on climate, soil, social setting, and historical patterns of land use and management. Globally, the most prominent mitigation options are improved agricultural land management and agronomic practices (e.g. nutrient use, tillage and residue management), restoration of organic soils and rehabilitation of degraded lands. Lower but still significant mitigation is possible with improved water and rice management; set-asides (i.e. temporarily unused agricultural land), land use change (e.g. conversion of cropland to grassland) and agroforestry; as well as improved livestock and manure management. Many mitigation opportunities use current technologies and can be implemented immediately.

Considering all GHG, the global technical mitigation potential from agriculture (excluding fossil fuel offsets from biomass production) by 2030 is estimated to be around 4500 (Caldeira et al., 2004) to 6000 million tonnes CO_2-eq/year (Smith et al., 2007a). Both global estimates are based on per-area or per-animal estimates of mitigation potential for each GHG and multiplied by the area available for that practice in each region. Corresponding economic potentials to the figures by Smith et al. (2007a) are estimated at 1500–1600, 2500–2700, and 4000–4300 million tonnes CO_2-eq/year with carbon prices of up to 20, 50 and 100 US$/t$CO_2$-eq, respectively. About 10% of the potential lies in "Economies In Transition", 20% in OECD countries and 70% in other countries. Agricultural GHG mitigation options are found to be cost-effective compared with non-agricultural options (e.g. energy, transportation, forestry) in achieving long-term (i.e. 2100) climate objectives.

The assessment of economic benefits of carbon sequestration is based on the literature on the social costs of carbon that estimate welfare losses from emissions of GHG (Watkiss et al., 2005; Stern, 2006). As 1 tonne of carbon sequestration compensates for 1 tonne of carbon emitted, the information on damages is used to estimate the benefits of sequestration. Carbon sequestration will lower concentrations of GHG in the atmosphere and thus limit global warming and related damages. The available information on damages from global warming is however uncertain and incomplete, which makes it less suitable for assessment of benefits of carbon sequestration. Another approach is to assess how carbon sequestration will limit the total economic costs to meet climate change policy objectives. A cost-effective set of measures to achieve the 2 °C target will involve a mix of GHG emission reductions and carbon sequestration in different sectors and countries worldwide. More carbon sequestration in European agriculture will allow to avoid other, more costly measures. These avoided costs can be interpreted as the welfare benefits of carbon sequestration. This is further elaborated in "Economic valuation" section.

In this paper, the following promising practices for the European agricultural sector related to mitigation by carbon sequestration both above and below ground are discussed: (i) agroforestry, (ii) introduction of hedges along agricultural plots, (iii) introducing cover crops in the rotation system and (iv) practices of low or no tillage. The potential and value of these practices are estimated.

Agricultural practices and the carbon cycle

Based on current land-based measurements, stock changes in agricultural soils in Europe, with the Urals as Eastern border, are considered to be a source with a flux of about 200 million tonnes of carbon (C) per year (Smith et al., 2005). This figure does not include emissions of other GHGs (CH_4 and N_2O) from animal farming, pasture and cropland. The forest sector in Europe is estimated to be a sink with a flux of about 380 million tonnes C/year.

Agricultural lands generate large CO_2 fluxes both to and from the atmosphere (IPCC, 2001; US-EPA, 2005; Smith et al., 2007b). Agricultural ecosystems hold large carbon reserves (IPCC, 2001), mostly in soil organic matter. On average 50–58% of organic matter consists of carbon (Platteau et al., 2006). Historically, these systems have lost more than 50 Pg C (Paustian et al., 1998; Lal, 1999, 2004) hereby releasing large amounts of CO_2. The level of soil carbon in soil is determined by the balance between inputs of organic matter, and its subsequent rate of decomposition and loss. Decomposition of soil organic matter is brought about by relatively complex biological processes. Soil organisms breakdown organic matter to obtain energy and nutrients along with the release of carbon dioxide (respiration). The rates of decomposition are affected by: (i) soil practices (e.g. tillage, the plant species (C:N ratio), manure inputs, etc.); (ii) the environment (temperature, rainfall, (an)aerobic conditions); (iii) soil characteristics (soil texture and biology, etc.). The main reasons for the decrease in organic matter content in conventional agriculture in N-W-Europe in the last decades are: the increase of the ploughing depth; the lower input of stable organic matter by means of organic manure and soil improvers; the decrease of ploughing crop residues; the increased conversion of grassland into arable land; more stringent manure application rules and a higher mineralization rate due to climate change (Platteau et al., 2006; Mulier et al., 2006; Mondelaers et al., 2009).

The carbon historically lost can be recovered by altering the current flux figures through improved management, thereby withdrawing atmospheric CO_2. Any practice that increases the photosynthetic input of carbon and/or slows the return of stored carbon to CO_2 will have a positive effect on carbon reserves, thereby stimulating 'carbon sequestration' and building carbon 'sinks'. Many studies, worldwide, have shown that significant amounts of soil carbon can be stored in this way, through a range of practices, suited to local conditions (Lal, 2004; Guang-Lu and Xiao-Ming, 2010). Soil carbon sequestration contributes an estimated 89% to the global technical mitigation potential (Smith et al., 2007b). Estimates suggest that 400–800 million tonnes C/year (equivalent to about 1400–2900 million tonnes CO_2-eq/year) could be sequestered in global agricultural soils with a finite capacity saturating after 50–100 years (IPCC, 1996).

More concretely, low and no tillage slow down the release of carbon to the atmosphere but will not help increase organic matter in the soil. The largest source of soil organic matter is the residue contributed by current crops. Cover crops or catch crops such as mustard seed or legumes contribute to the organic matter stock. This effect is further enhanced by the introduction of woody species on agricultural land in the form of hedgerows, woodlots and trees (agroforestry). Practices of replanting trees and hedges increase carbon sequestration above and in the soil and have important potential to capture CO_2 from the atmosphere and store them for longer periods. In "Agricultural practices and their carbon sequestration potential per ha" section, we will consider in more detail the potential of (i) agroforestry, (ii) cover crops and (iii) low or no tillage (Fig. 1).

Economic value of climate change mitigation

To assess the value of carbon sequestration by ecosystems, theoretically two approaches can be followed. The first approach is based on avoided costs to reduce CO_2 emissions in other sectors, when a certain policy target related global warming has to be met.