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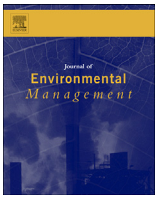

Review

Carbon farming economics: What have we learned?

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ABSTRACT

This study reviewed 62 economic analyses published between 1995 and 2014 on the economic impacts of policies that incentivise agricultural greenhouse (GHG) mitigation. Typically, biophysical models are used to evaluate the changes in GHG mitigation that result from landholders changing their farm and land management practices. The estimated results of biophysical models are then integrated with economic models to simulate the costs of different policy scenarios to production systems. The cost estimates vary between \$3 and \$130/t CO_2 equivalent in 2012 US dollars, depending on the mitigation strategies, spatial locations, and policy scenarios considered. Most studies assessed the consequences of a single, rather than multiple, mitigation strategies, and few considered the co-benefits of carbon farming. These omissions could challenge the reality and robustness of the studies' results. One of the biggest challenges facing agricultural economists is to assess the full extent of the trade-offs involved in carbon farming. We need to improve our biophysical knowledge about carbon farming co-benefits, predict the economic impacts of employing multiple strategies and policy incentives, and develop the associated integrated models, to estimate the full costs and benefits of agricultural GHG mitigation to farmers and the rest of society.

Contents

1. Introduction

The risk posed by global warming due to anthropogenic greenhouse gas (GHG) emissions will be a major challenge for human beings in the coming decades (IPCC, 2007; World Bank, 2010). The agricultural sector is one of the largest producers of

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nitrous oxide (N_2O) and methane (CH_4), which are two GHGs with significant global warming potentials (GWP). The GWP of N_2O and CH_4 are 310 and 21, respectively – which means that they will trap 310 and 20 times more heat than CO_2 over a 100 year time horizon (Povellato et al., 2007; Jackson et al., 2009). Agriculture produces about 6.1 giga tonnes of carbon dioxide equivalents (CO_2e) per year, accounting for 10 to 12 percent of global GHG emissions (Bonesmo et al., 2012).

There is increasing evidence that agriculture can play an important role in removing GHG from the atmosphere (Lal, 1999; Bustamante et al., 2014). For example, agricultural soils offer the potential to absorb CO_2. Lal (2004) suggested that, globally, agricultural soils can offset about 15 percent of global GHG emissions. For Australia, Garnaut (2008) estimated that agriculture has a potential to mitigate 84 million tonnes of CO_2e GHG per year, equalling about 15% of the national GHG emissions (Department of Agriculture, Fisheries and Forestry, 2012).

In recent years, policies aimed at encouraging GHG mitigation activities have been adopted in different parts of the world. These include the European Union Emissions Trading Scheme, Japan's Voluntary Emission Trading Scheme, New Zealand's Emissions Trading Scheme, and the Emission Reduction Fund in Australia.[1] Such policies can provide incentives to encourage the adoption of carbon farming practices by landholders. Carbon farming practices refer to those agricultural activities that can sequester carbon and/or reduce GHG emissions. Carbon sequestration includes conservation tillage, continuous cropping, and rotational cropping that increases soil carbon, or afforestation on agricultural land which stores carbon in vegetation (Antle et al., 2002a; Capalbo et al., 2004; Antle et al., 2007a; Bosch et al., 2008; González-Estrada et al., 2008; Hunt, 2008). GHG emission mitigation strategies include livestock and fertiliser management changes (Khakbazan et al., 2009; Berdanier and Conant, 2012; Bonesmo et al., 2012).

From an economic perspective, one expects farmers to only adopt a carbon farming practice if the change in practices is profitable. There have been several studies evaluating the economics of agricultural GHG mitigation. These studies address, for example, the costs and profits of carbon farming for landowners, the efficiencies of various mitigation strategies, and the effectiveness of different policy incentives (e.g. Antle et al., 2001; De Cara et al., 2005; Kragt et al., 2012).

Notwithstanding the range of economic case-studies, there exists no systematic review that brings together the body of work on the economics of agricultural GHG mitigation. This study attempts to fill this knowledge gap by conducting a comprehensive review of the literature and to identify key lessons by examining the primary tools used, policy scenarios assessed, and mitigation costs estimated.

2. Method

We reviewed economic analyses of carbon farming published in peer-reviewed journals between 1995 and 2014. A search for relevant publications was conducted in Google Scholar, Wiley Online Library, Web of Science, Science Direct, and EconLit. We used the following search terms: carbon farming economics, greenhouse gas agricultural economics, climate change agricultural economics, soil carbon, farmland GHG emission, cropland GHG emission, methane reduction, agricultural carbon tax, agricultural carbon credit, agroforestry, REDD, and GHG voluntary market. The returned literature included many studies that focused on the economics of GHG mitigation in non-agricultural sectors. We therefore ran a search paring the above key words with search terms to reflect specific types of carbon farming practices: conservation agricultural practices, conservation tillage, no-till, minimum-till, continuous cropping, rotational cropping, afforestation, crop residue retention, farming land conversion, fertiliser management, and rotational grazing. All search terms were typed without quotation marks.

This search initially yielded 139 papers published in peer-reviewed journals. The full text of these 139 papers was checked. Only studies that included empirical analysis of the economics of agricultural GHG mitigation were retained. After this process, 62 studies were identified as relevant. For each of these papers, the following were recorded: the studied region, the type of farming system, the types of GHGs covered, biophysical models used, economic models used, policy incentives studied, and research findings.

3. Results and discussion

Many studies have integrated biophysical and economic models to examine the feasibility of GHGs mitigation in agriculture. The results of biophysical models, such as estimated on-farm GHG emissions under different carbon farming practices, are necessary inputs for economic models. Economic models are then used to estimate the expected farm revenues and costs associated with those carbon farming strategies.

3.1. Biophysical models in carbon farming economics

Biophysical models typically incorporate information on soil types, climate (e.g. rainfall, temperature), initial or historical land use records, plant types, and livestock structure. These models estimate, amongst other things, crop- and livestock yields, vegetation growth, GHG emission levels, and soil carbon levels.

Biophysical models that have been used include the following (Table 1):

i) CENTURY, a generalised-biogeochemical ecosystem model simulating nutrient dynamics (Parton et al., 1988);
ii) APSIM (Agricultural Production Systems Simulator), a process-based model on a paddock scale (Keating et al., 2003);
iii) NCAT (National Carbon Accounting Toolbox), an Australian predictive model for carbon flows in forest and agricultural systems (Australian Greenhouse Office, 2006);
iv) EPIC (Environmental Policy Integrated Climate), a model that operates on a daily time step and simulates crop production, soil carbon and nitrogen (Sharpley and Williams, 1990)[2]; and
v) CALM (Carbon Accounting for Land Managers), an online calculator that can be used to estimate GHG emissions on farm scale (Lloyd, 2008).

These models share some commonalities. They all provide estimates of the changes in soil carbon caused by varying carbon farming practices. Except for NCAT, the models also consider nitrogen emissions in agricultural systems. Typically, the models are capable of simulating multiple carbon farming practices, such as crop rotation, fertilisation, and tillage (Table 1).

There are also some notable differences among the models. CENTURY, APSIM, and EPIC contain sub-modules for soil GHG

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[1] http://www.climatechange.govt.nz/emissions-trading-scheme/about/international-examples.html.

[2] Earlier versions of EPIC were called Erosion Productivity Impact Calculator.