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Greenhouse gas emissions from different crop production and management practices in South Africa

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Application of synthetic (N) fertiliser (such as urea) and incorporation of crop residues into soil result in nitrous oxide (N_2O) emissions. Similarly, application of urea and lime to the soil results in carbon dioxide (CO_2) emissions. Greenhouse gases (GHGs) emanating from application of synthetic fertiliser, lime and crop residues retained in the field after harvest during field crop production in South Africa were calculated in this study. The objective was to establish GHG profiles of the field crops in South Africa that can inform national mitigation plans that are currently lacking details regarding the agriculture sector. The calculations used *Agriculture and Land Use National Greenhouse Gas Inventory Software* which is based on the Intergovernmental Panel on Climate Change Guidelines for National GHG Inventory. GHG emissions were calculated and compared among different crop production and management practices. It is estimated that production of field crops resulted in a total of 5.2 million tonnes of CO_2 equivalent (CO_2-eq) emissions in South Africa in 2012. Application of synthetic fertiliser contributes the highest emissions with 57% of national total crop CO_2-eq emissions, followed by addition of lime (30%) and crop residues retained in the field (13%). Production of cereal crops accounts for 68% of national total field crops' GHG emissions followed by other field crops (14%), legumes and oilseeds (11%) and vegetables (7%). Cultivations of maize, wheat and sugarcane result in highest commodity emissions. Highest GHGs per area planted were from the production of tomatoes with 1.65 t of CO_2-eq ha^{-1}. These results show that mitigation plans of emissions from field crops in South Africa need to focus more on sustainable improvement of soil fertility, optimum application of synthetic N fertiliser and crop residues.

1. Introduction

Global climate is changing primarily because of anthropogenic greenhouse gas (GHG) emissions into the atmosphere. Anthropogenic GHG emissions since the pre-industrial era have driven large increases in the atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (IPCC, 2014). In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was developed with the objective of stabilising global GHG concentrations in the

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atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (United Nations, 1992). It is therefore one of the objectives of South Africa's national policy on climate change (South Africa, 2011) that the country makes a fair contribution to the global effort to stabilise the GHG concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a time frame that enables sustainable economic, social and environmental development. To achieve this objective, the UNFCCC encourages signatory countries to support research and systematic observations on both climate change adaptation and mitigation of GHG emissions.

South Africa is a major emitter of GHGs and accounts for 65% of Africa's emissions (South Africa, 2013). The economy, which is largely based on the combustion of fossil fuels, makes the energy sector the main emitter of GHG emissions in the country (Blignaut et al., 2005). In 2007 it is estimated that 78% of emissions resulted from fuel combustion, 15% from industrial processes and 7% from other sectors (Winkler and Marquand, 2009). The country is the 42nd largest emitter per capita in the world and is among a number of developing countries that are likely to face globally imposed emissions constraints in the near future (South Africa, 2012). The government has identified carbon pricing and carbon budget approaches as two instruments that help to establish a strategy to mitigate national GHG emissions (South Africa, 2012). The country is currently implementing an economy-wide carbon tax regime to mitigate the anthropogenic GHG emissions (National Treasury, 2014). The agriculture and forestry land use sectors are currently excluded during the first 5 years (2016–2020) of the national carbon tax regime largely due to administrative difficulties in measuring and verifying emissions from these sectors (National Treasury, 2014). Modelling for the national Long-Term Mitigation Scenarios in 2008 indicated that mitigation in agriculture and other sectors excluding energy and industrial processes could make a significant contribution to national mitigation in the 2010–2020 period, but more investigation is needed to understand the requirements for establishing programmes in these areas (DEA, 2011). However, to date, agricultural research and development have generally remained focused on sustainable yields and reducing the effects of environmental variability, and agricultural policies and interventions in South Africa still lack an integrated approach which incorporates ecological and social dimensions (Vetter, 2009).

During the last four decades, global agricultural land increased due to conversions from other land uses, a change driven largely by increasing demands for food from a growing human population (IPCC, 2006; Wang et al., 2013). In South Africa, cropland and grasslands are estimated to have increased by 16.7% and 1.2%, respectively, between 2000 and 2010 (DEA, 2014). Land use changes, irrigation, soil nutrient drainage, fertiliser application practices, and changes in crop and livestock patterns all contribute to changes in soil carbon (C), nitrogen (N) dynamics and ultimately atmospheric GHG emissions (Wang et al., 2013; Ogle et al., 2014). The land sector in South Africa is a net sink of GHG emissions (average 19 million tonnes of CO_2 in 2010) which is dominated by a biomass carbon pool from grasslands and forest lands, and small contributions from soils (DEA, 2014). Cropland is a net source of 39 thousand tonnes of CO_2 (DEA, 2014).

Greenhouse gas emissions from agricultural practices are not well known compared to other sectors (Rajaniemi et al., 2011). Acceleration of the global N cycle due to human activities is probably the major cause of an increase in the atmospheric N_2O concentration of 0.7 ppb per year (Bouwman et al., 2002). During the past few decades, global CH_4, CO_2 and N_2O concentrations in the atmosphere increased at rates of 0.8%, 0.5% and 0.3% per year, respectively (Wang et al., 2013). Anthropogenic sources of N_2O emitted from managed soils are the application of synthetic N fertilisers and animal manure, and crop residues retained in the field (Stehfest and Bouwman, 2006). However, in southern Africa crop residues are often grazed, removed or burned after each harvest (Murungu, 2012). Most N_2O is produced in soils through biological processes of nitrification and denitrification which are enhanced by availability of N (Kasimir-Klemedtsson et al., 1997; Bouwman et al., 2002; Serrano-Silva et al., 2011; Signor and Cerri, 2013; Valentini et al., 2014). Temperature, moisture, and soil biological, chemical and physical characteristics are of great importance for nitrification and denitrification because they influence the microbial activities (Imer et al., 2013; Signor and Cerri, 2013; Wang et al., 2013).

Agricultural soils in South Africa emitted 14.9 and 17.8 million tonnes of CO_2 equivalent (CO_2-eq) in 1990 and 1994, respectively (Blignaut et al., 2005). The agriculture sector contributed 4.9% of national total GHG emissions in 2000 (DEAT, 2009). Cropland accounts for less than 1% and 21% of national total GHG emissions and agricultural emissions, respectively (DEA, 2014). Between 2000 and 2010 the annual GHG emissions produced by the sector increased by 38% (DEA, 2014). In all the inventories compiled in the country, emissions from crop production have not been disaggregated into commodity sources and inputs applied to the soil. Therefore the primary aim of this study was to estimate national GHG emissions from synthetic N fertiliser (including urea), lime and crop residues applied to soil during crop production. This is the first study in the country to develop a profile of GHG emissions from field crops. Availability of activity data limited previous national inventories to focus on emissions from manure management without investigating contributions by each field crop. Tools were also not robust enough to appropriately integrate all the information.

2. Methodology

2.1. Activity data

This study estimated GHGs produced from cultivation of field crops using data on crop residues retained in the fields after harvest, synthetic fertiliser (including urea) and lime applied during cultivation. National climate and soil data were also used in the analysis.