Agricultural Systems 166 (2018) 124–134

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Review

A review of greenhouse gas emissions from the agriculture sector in Africa

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ARTICLE INFO

Keywords:
Enteric fermentation
GHG intensity
Crop management
Livestock production
Smallholder farming

ABSTRACT

Agricultural activities contribute to greenhouse gas (GHG) emissions to the atmosphere. The GHG emissions from agriculture in Africa are among the fastest growing emissions in the world. The increasing food demand due to population growth in Africa and other parts of the world will continue to influence emissions in the continent. This study provides a review of GHG emissions from the agriculture sector in Africa between 1994 and 2014. The policy requirements for the mitigation of the emissions in the continent are also discussed. The continent was divided into five broad regions according to prominent agro-ecological zones. The data analyzed were from the national GHG inventory reports, national communications to the United Nations Framework Convention on Climate Change, Food and Agriculture Organization of the United Nations, Emissions Database for Global Atmospheric Research and material from the literature. The highest and lowest annual emissions from these sources defined the ranges of emissions, except in 2014 when there was only a single source. Between 1994 and 2014, the GHG emissions from agriculture in Africa increased at an average annual rate of between 2.9% and 3.1%. The emissions ranged between 0.44 Gt and 0.54 Gt CO_2 equivalent in 1994, 0.66 Gt and 0.79 Gt in 2010, and 0.87 Gt in 2014. The rates of emissions are not homogeneous in all regions of the continent. East Africa and Southern Africa are the largest producers of emissions from agriculture in the continent with 34% and 27% respectively. The regions with the lowest emissions are Central and North Africa with a maximum of 10% of the total emissions from the continent. Enteric fermentation is the largest source of emissions from agriculture in the continent with more than half of the total. Focussed research is required to remove large uncertainties that exist in the GHG emissions from Africa so that appropriate mitigation plans can be developed. As a result of Africa's high vulnerability to the adverse impacts of climate change, the continent's main focus is on building resilience and improving food security. Plans to mitigate GHG emissions are not explicit and only appear as secondary or co-benefits of adaptation. Consequently, mitigation of emissions from agriculture may need to be identified and formulated within the broad food security and economic development but contextualized to the main farming systems practised in the continent.

1. Introduction

Agriculture is the primary sector of almost every African economy (Saghir, 2014; Valentini et al., 2014; Ba, 2016). About 65% of the total labour force in Africa is employed in the agriculture sector, which contributes about 32% of the continent's gross domestic product (GDP), reflecting the relatively low productivity in the sector (Chauvin et al., 2012; Ba, 2016). Agricultural land expansion (extensification) has been an important component of production growth in places such as Africa and Latin America (Tilman et al., 2011; Herrero et al., 2016). Production in Africa could also be increased by agricultural intensification (i.e. achieving higher yields through increased inputs, improved agronomic practices, improved crop varieties, and other innovations) (Hickman et al., 2011; Tilman et al., 2011). In developing countries, agriculture is a crucial sector for driving the green economy (Musvoto et al., 2015). However, land clearing, soil cultivation, and the manufacture and use of nitrogen (N) fertilizer all emit greenhouse gases [GHG] (Tilman et al., 2011).

Despite impressive economic performance of not less than 4.5% during the first decade of this millennium in sub-Saharan Africa (SSA), agricultural transformation has been slow and growth sluggish (Chauvin et al., 2012). Agricultural production in SSA grew at an average annual rate of between 2.6% and 3.1% from 1961 to 2008 (Fuglie and Rada, 2013). Annual agricultural GDP growth in SSA averaged 2.3% in the 1980s (lower than the average population growth) and 3.8% during the 2000s but this growth has been mostly

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https://doi.org/10.1016/j.agsy.2018.08.011
Received 2 October 2017; Received in revised form 8 June 2018; Accepted 20 August 2018
0308-521X/

based on area expansion (Chauvin et al., 2012; Fuglie and Rada, 2013). Total food production in SSA has been growing but at a very slow rate of less than 1% per year (Salami et al., 2010; Chauvin et al., 2012). There are varying factors that lead to the slow growth of agricultural output in Africa. Low spending on agriculture by most African farmers (average of 1% to 6% of total expenditure since 1980), low adoption rates of new technologies, inaccessibility to markets for both inputs and outputs, continuous decline of soil nutrients, and an unskilled labour force are prominent impediments to agricultural growth in the continent (Salami et al., 2010; Chauvin et al., 2012; Fuglie and Rada, 2013).

A total of 85% of annual available fresh water in the continent is being withdrawn for agricultural use (Inocencio et al., 2003). Agriculture is the biggest user of water in Southern Africa, accounting for 60% to 75% of total water use (Lange et al., 2007; Blignaut et al., 2009; Lorentzen, 2009). Agriculture uses 75% of water withdrawals in West Africa although only around 1% of the arable land is irrigated (ECOWAS, 2006). The agricultural sector is responsible for nearly 75% of total water withdrawal in the Nile basin where even small-scale farming in the drier lower basin relies largely on surface water and groundwater (EEAA, 2010; Swain, 2011). Approximately 50% of potential arable land in the Nile basin is irrigated, of which 98.7% is in the climatically dry Egypt and northern Sudan region (Swain, 2011). Use of water in agriculture especially during irrigation influences N dynamics in the soil and ultimately nitrous oxide (N_2O) emissions.

Currently livestock is one of the fastest growing agricultural subsectors in developing countries (Thornton, 2010). East Africa had the most heads of cattle and buffalo between 2000 and 2011 due to the export demand to the Middle East (Gerber et al., 2013; FAO, 2014, 2017b). Ethiopia has the largest national livestock population (most of which are local breeds fed on natural pastures and crop residues) in Africa (FAO and NZAGGRC, 2017) and is ranked tenth in the world (FAO, 2015; Mayberry et al., 2017). Most ruminants raised for meat in SSA have lower feed efficiencies (Herrero et al., 2013). Livestock in grazing systems consume mostly grass, whereas those in mixed systems consume a wide array of feeds (Herrero et al., 2013; Moeletsi and Tongwane, 2015). In recent decades, increasing numbers of animals are raised in intensive production systems where they are fed a diet rich in protein content (Koneswaran and Nierenberg, 2008; Scholtz et al., 2013; Herrero et al., 2013; Gaitan et al., 2016).

Use of fertilizer per hectare (ha) of arable land is increasing in Africa but the consumption rate remains low (FAO, 2013, 2014; Ba, 2016; Lu and Tian, 2017). Average fertilizer applied on croplands in SSA peaked at around 10 kg of N ha^{-1} in the 1980s and has since fallen to under 8 kg ha^{-1}, representing rates far below those of other developing countries (Fermont et al., 2010; Hickman et al., 2011; Fuglie and Rada, 2013; Tadele, 2017). Fertilizer application rates in other parts of the continent are higher and average about 35 kg ha^{-1} since the mid-1990s (Salami et al., 2010; Fuglie and Rada, 2013; EEAA, 2010; Tongwane et al., 2016). Mineral fertilizers only contributed 25–29% of the overall total N input in Africa, a reflection of the low purchase of mineral fertilizers in many countries of the continent (Liu et al., 2010). The global average N use intensity was 94 kg ha^{-1} in 2005 (Tilman et al., 2011). Extensive planting of soybeans and other leguminous crops in the continent make biofixation the single largest N input in the continent (Liu et al., 2010). Fertilizer applied during crop production is heterogeneous among African countries (Jayne and Rashid, 2013; Sheahan and Barrett, 2017). However, blanket application of fertilizer in Africa remains common (Jayne and Rashid, 2013; Ezui et al., 2016). In Egypt, where the area of cultivated crops increased significantly, application of N increased by 144% between 1990 and 2000 and farmers apply over 360 t ha^{-1} of this nutrient (EEAA, 2010; FAO, 2014). Similar to N fertilizer, agricultural lime is unaffordable and inaccessible to smallholder farmers in Africa (Tadele, 2017).

Croplands are both a sink and a source of GHG emissions (Kim et al., 2016). It is common practice in much of rural SSA that farmers remove all crop residues after harvest (Suckall et al., 2015). Crop diversity in the continent is more pronounced in West Africa than in other regions and many of the crops planted in this region are unique and not well researched (Tadele, 2017). Cassava is the major crop grown in West Africa (Leff et al., 2004) and the general belief that this crop does not require fertilizer since it can do well in degraded lands, makes farmers barely use fertilizer (Fermont et al., 2010). A mixture of wheat, barley, maize and rice dominates large crop areas in North Africa (Leff et al., 2004). Maize, sorghum, wheat and millet are common staple crops in Southern Africa (Wenzel, 2003; Christiansen, 2008; Tongwane et al., 2016). The only regions globally where a cereal is not the dominant crop are the Caribbean and central Africa (Leff et al., 2004). Production of cereal crops is the major source of GHG emissions in Africa because of the large areas of lands they occupy when compared to other crops (Tongwane et al., 2016). GHG emissions from croplands in SSA depend on both natural variations associated with climate and soil type and management factors including nutrients (particularly fertilization) and crop type (Kim et al., 2016).

In 2005, agriculture contributed between 10% and 12% of total global anthropogenic GHG emissions (Vermeulen et al., 2012). Current understanding of GHG emissions in SSA is particularly limited when compared to the potential the continent has as both a GHG sink and a source (Kim et al., 2016; Boateng et al., 2017). Limited data and information on agricultural production in Africa make it difficult to quantify the contribution that the continent could make towards global mitigation of GHG emissions. This review studied GHG emissions from agriculture in Africa with a view to establishing a synoptic baseline for the continent that would assist in the planning of mitigation activities in the sector. It analyzed characteristics of GHG emissions from the agriculture sector in Africa for the years 1994, 2000, 2005, 2010 and 2014. Emissions from other land use types including forestry were not considered. Only GHG sources based on the Intergovernmental Panel on Climate Change (IPCC) approaches were analyzed and sinks are excluded. The review advances understanding of GHG emissions from agriculture previously presented by other authors (e.g. Valentini et al., 2014) and various publications made by the Food and Agriculture Organization of the United Nations (FAO, 2014, 2015). The major sources of agricultural emissions are identified per agro-ecological region.

2. Approach to this review

The agroclimatological zones in Africa are diverse. They range from the dry barren desert in the North, through the rich soil of the Rift, Nile and Niger valleys, to the southern extremes (Leff et al., 2004). Based on this diversity, Africa can be divided into five broad agro-ecological zones (Table 1). These zones closely resemble regional economic communities of the African Union. Nearly all countries had compiled their first and second communications to the United Nations Framework Convention on Climate Change (UNFCCC) and therefore emissions for the base years 1994 and 2000 were available for the majority. However, few countries have developed third national communications and GHG emissions beyond 2000. Primary data for the years 1994 and 2000 came from national communications and the UNFCCC portal (http://di.unfccc.int/NonAnnex.aspx). In the event that data from national communications were not available in these years, but were reported in a year either before or after them, those data were used to fill the respective gaps. African national GHG inventories and communications are not always consistent and continuous during the reporting periods. Reporting of the emissions is aggregated into broad categories that may not allow detailed analysis of sources by type. For instance, N_2O emissions from agricultural soils, including emissions from synthetic fertilizers, manure and crop residues, are treated as a single reporting category (Tubiello et al., 2013). Emissions from enteric fermentation are aggregated and do not show contributions by animal type. This makes it difficult to perform sensitivity analysis of the emissions. As a result, while national inventories and global databases