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Alan Iwaasa, H.A. (Bart) Lardner,
Mike Schellenberg, Walter Willms
and Kathy Larson

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Intra-Annual Variability of the Greenhouse Gas Balance of a Sylvo-Pastoral Ecosystem in Semi-Arid West Africa

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Key words: Ecosystem functioning, animal-soil-plant interactions, landscape, Senegal

Introduction

Extensive pastoral ecosystems, a quarter of the earth's land surface, are said to be major contributors to global warming. In sub-Saharan Africa, they are supposed to be responsible for the highest rates of greenhouse gas (GHG) emissions per unit of animal product (Steinfeld *et al.*, 2006). Main reasons put forward are the low productivity of herds, low management level of pastures and high methanogenic potential of feed intakes. Pastoral landscapes are characterized by constraining climatic conditions with little precipitation falling in a limited time frame that creates high seasonal variability in forage availability. The GHG balance for these landscapes is commonly calculated at regional and yearly scales. This study proposes a dynamic vision of a sylvo-pastoral landscape functioning by examining the intra-annual variability of the GHG balance. The objectives of this study are to describe the functioning of the sylvo-pastoral ecosystem during a full year and to propose a first assessment of the intra-annual temporal variability of its GHG balance. The study is original in its capacity to integrate the various components of the ecosystem (animals, soil, plants) and to consider all components of the GHG balance at the landscape level.

Material and Methods

The studied landscape is a circular area of 15 km centred on the Widou borehole (15°59'N, 15°19'W, 706 km²) representative of the sylvo-pastoral Ferlo Region in Sahelian zone of West Africa (North of Senegal). For this study, an original measurement protocol was implemented from May 2014 to October 2015 to estimate full GHG emissions and carbon accumulation in the studied landscape. Methane emissions from livestock enteric fermentation were evaluated using indirect approach: according to livestock resource intake and digestibility estimated through near-infrared spectroscopy analysis applied to faeces (F-NIRS) as described in Decruyenaere *et al.* (2009). Nitrous oxide (N_2O) and methane (CH_4) emissions in the soil and water due to manure deposition were measured with the static chamber method proposed by Khalil *et al.* (1998). The other sources of emissions (CH_4 from termites, CO_2 from fuel consumed by borehole motor pump and CO_2 from bush fires) were evaluated with the use of emission factors proposed in the literature. In the soil, net carbon exchange was quantified from the difference between total carbon inputs and outputs in the soil. Total carbon accumulation in trees aboveground and belowground biomass was evaluated with in situ surveys and specific allometric equations available in the literature for the main species encountered in the region. The evaluation of monthly variations of herd composition (by a survey among the herders) and herd weight evolution (in situ measures) were used to evaluate carbon sequestrated in the livestock. Supplementary data on herbaceous biomass production were also collected to better explain the dynamic functioning of the studied ecosystem. The GHG balance for the whole landscape unit was calculated by subtracting the total of carbon accumulation from the total GHG emissions.

Results and Discussion

Livestock related biomass fluxes and stocks

Total livestock in Widou area is 31560 Tropical Livestock Units (one TLU is equivalent to an animal of 250 kg live weight) with 49% cattle, 32% sheep and goats, 19% donkeys and horses. The study shows that this area supports a stocking rate ranging from 0.34 to 0.21 TLU/ha depended on livestock seasonal movements. Besides water, the herbaceous layer constitutes a basic element in the functioning and survival of the pastoral systems in semi-arid regions such as our studied landscape. The peak of forage availability is observed in September with a total aboveground herbaceous biomass of 1.49 t DM/ha and a total belowground biomass of 0.22 t DM/ha. Livestock ingest daily 2.6 to 7.1 kg DM/TLU according to seasons and herbaceous biomass availability. Between 26.4% and 37.2% of the biomass is consumed during the night. At the landscape level, only 27% of total produced biomass is ingested by the animals in one year, the rest returns to soil or is burnt in bush fires.

Temporal variability of the GHG balance at the whole ecosystem level

Figure 1 shows the monthly variations of the full GHG balance for the studied landscape. The GHG balance is positive and varies between 9,996.2 t CO_2-eq/month and 80,632.1 t CO_2-eq/month during the wet season (from July to October). However, during the two dry seasons (cold dry season from November to February and warm dry season from March to June) the GHG balance is negative and varies between -55,769.4 t CO_2-eq/month and -6,992.7 t CO_2-eq/month. At the landscape level and over one full year the full GHG balance is –0.02 t C-eq/ha. This negative value for the GHG balance indicates that the GHG emissions are compensated by total carbon accumulation in the soil, trees and animals. Negative values were also found for temperate pastoral ecosystem (Soussana *et al.*, 2007). However this value is lower than the ones observed under temperate conditions because of lower carbon sequestration potentials in soils under semi-arid tropical conditions due to limited rainfalls and high temperatures (Kotir, 2011).

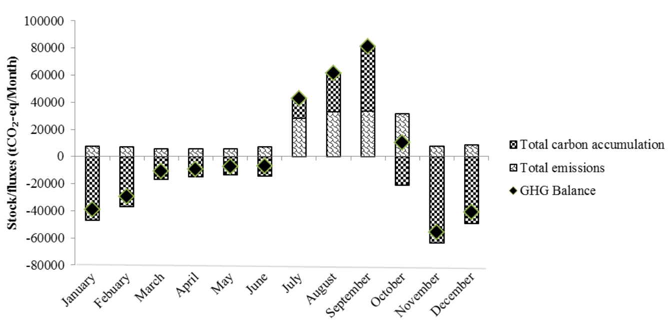

Figure 9. Temporal variability of the full GHG balance at the whole landscape level.

Conclusions and Implications

This study shows a strong temporal variability of the full GHG balance in a semi-arid sylvo-pastoral region. At the whole Widou borehole coverage area level, the yearly GHG balance appears slightly negative, indicating a more or less equilibrated state between the total GHG emissions and the total carbon accumulation in soils, tree and livestock. Transhumance plays a key role in this equilibrium because herders carefully adapt the livestock stocking rate to the available biomass.

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No Difference in Carbon Dioxide Emissions from Grazed and Non-Grazed Temperate Grassland Soils

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Key words: Greenhouse gases, soil microbes, rangelands, carbon emissions, carbon mineralization

Introduction

The emission of anthropogenic greenhouse gases (GHG) is driving global climate change. Rangeland soils have high potential to reduce GHG concentrations via soil carbon sequestration (Piñeiro et al., 2010). Due to the areal extent of rangelands, they may serve as a significant sink of GHG and help mitigate global climate change, provided appropriate management is taking place (Smith et al., 2008). The main drivers of GHG flux from soils are microorganisms (bacteria and fungi) that respire CO_2. The community composition of microorganisms changes over climatic gradients, but they are also sensitive to changes in their local environment (Steenwerth et al. 2002). Cattle grazing can alter the pedosphere by altering litter cover, and soil temperature and moisture. The goal of this project is to examine the impact of cattle grazing on CO_2 emissions from grazed and non-grazed rangelands across a broad precipitation gradient in the Canadian Prairies.

Materials and Methods

We established 15 study locations throughout the grasslands of Alberta, Canada to measure GHG emissions. Study sites were located along a climate gradient within 3 natural subregions of Alberta (Parkland, Mixedgrass Prairie and Foothils Fescue). Each site included a plot grazed by cattle and a non-grazed (cattle exclosure) plot. Exclosures were approximately 30 x 30 m, and at least 15 years old. In the spring of 2015, we installed 2 static gas chambers (15 x 17 x 66 cm) in each subplot and collected gas samples bi-weekly from May through July, then every 3 weeks until October. At each sampling time 4 gas samples were collected (0, 10, 20 and 30 min), which were used to calculate flux (Lambert and Frechette, 2005). GHG concentrations were measured by gas chromatography (CP-3800 GC, Varian). We used soil probes to measure soil temperature and moisture continuously in each subplot. Soil samples (0-5 cm) were collected three times (spring, summer and fall) to determine soil characteristics (e.g. pH, organic carbon and total nitrogen). Differences in CO_2 flux were tested with repeated measures analysis of variance in which treatment and region were fixed effects.