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Assessment of Trace Gas Emissions From Wild Fires in Different Vegetation Types in Northern Ghana: Implications for Global Warming

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Abstract

Biomass burning in Northern Ghana is a major cause for concern because of its potential contribution to global warming, hence climate change. This study assessed the emission of trace gases from human activities in the Guinea savanna of Northern Ghana using the guidelines of the Intergovernmental Panel on Climate Change. Carbon content of biomass was determined from four different vegetation covers in the study area; namely, widely open savanna woodland, grass/herb with scattered trees, open savanna woodland and closed savanna woodland. Under each vegetation cover, five plots (1 m x 1 m) were demarcated for the estimation of above-ground biomass density. Using the combustion furnace method, emitted carbon, methane and carbon monoxide were estimated. Results showed that the emitted methane (CH_4) and carbon monoxide (CO) differed significantly ($p<0.05$) under all the vegetation types. The gases were in perfect correlation ($r=1.00$) with the quantity of above-ground biomass density and carbon released, with more CO being emitted. Emission of CH4 and CO per hectare of burnt area in the open savanna woodland category was the highest with 0.001719 ton and 0.045119 ton respectively. Over time, emission of these gases may increase their atmospheric concentration, causing major health problems. The contribution to global warming, thus climate change, may also become quite significant. This underscores the fact that existing flaws in the wild fire management policy of Ghana must be effectively dealt with and appropriately implemented with regular reviews to reduce the annual wild fires that are very rampant in Northern Ghana, especially during the dry season.

Keywords: Trace gas emission, global warming, biomass burning, wild fires, Guinea savanna

1. Introduction

One of the most debated and a researched issue is the increase in concentration of greenhouse gases into the atmosphere and its effect on global warming (Schils et al., 2008). Typically major land-use changes, particularly through widespread use of wild fires, contribute significantly to atmospheric greenhouse gas emissions (Shimada et al., 2000). Two major causes of bush fires have been generally recognized: natural and anthropogenic (Jones, 1979; Langaas, 1995). Most of these fires, whether accidental or deliberate, are assumed to be generated by humans during dry periods, which vary between ecosystems and climate zones (Jones, 1979; Korem, 1985). Elsewhere around the globe, wild fires occur regardless of season. Australia, for example, is prone to bushfires irrespective of the season. Summer and autumn seasons are, however, considered to be the vulnerable periods in southern Australia, while in the Northern Territory experiences most of its fires in winter and spring (Middelmann, 2007). Studies on annual spatial distributions of burnt areas across the United States have shown the seasonal peak of biomass burning generally occurring during June to August (Zhang & Kondragunta, 2008). Africa has been called a 'fire continent' (Trollope & Trollope, 1996) because of pervasive anthropogenic fires that burn the savanna vegetation annually (Mbow et al., 2000; Reid et al., 2000; Laris, 2002; Danthu et al., 2003). Farmers and pastoralists in Africa have developed traditional ways of avoiding the overwhelming nature of fire. In Senegal they practise early season grass burning because they find it safest and most beneficial (Bucini

& Lambin, 2002). 'Green flush' from perennial grasses and landscape protection from destructive fires is also considered to be the reason for early season burning (Mbow et al., 2000). Meanwhile, in Mali, the earliest burning is carried out to suppress the growth of unpalatable grasses that have no use for grazing (Laris, 2002). In the savannas of Ghana, bushfires, which are mostly man-made, are very common. These fires are typically grass fires and their intensity is usually lower than that of the forest fires (Bagamsah, 2005).

In tropical savanna woodland regions, the frequency of bush fires is on the increase, with the rise in population pressures and intensive use of rangeland. These ecosystems naturally consist of layers of grass interspersed with trees and shrubs, with an estimated area of about 1900 million hectares (Bolin et al., 1979). Some of the extensive uses of fires in these tropical regions include shifting cultivation and deforestation, and clearances of agricultural residue are some of the extensive uses of fire in the tropical regions (Crutzen & Andreae, 1990; Hao et al., 1990). Biomass burning is a large source of atmospheric carbon and a variety of greenhouse and trace gases, aerosols and pollutants that may significantly influence climate and atmospheric chemistry, particularly in the tropics (Hao & Liu, 1994; Rudolph et al., 1995; Andreae, 1997; Korontzi et al., 2003; van der Werf et al., 2010). Bush fires in the savanna region of African result mostly from human activities, and may produce as much as a third of the total emissions from biomass burning across the globe (Hao et al., 1990; Cahoon et al., 1992; Stott, 1994). In recent decades, the implication of this has become apparent as studies began to establish a link between biomass emissions and the global budgets of many radioactively and chemically active gases such as carbon dioxide, carbon monoxide, methane, nitrous oxide, tropospheric ozone, methyl chloride and elemental carbon particulate (Andreae, 1990; Hao & Liu, 1994; Rudolph et al., 1995; Korontzi et al., 2003). Therefore, biomass burning is now recognized as a significant global source of emission contribution.

However, despite this recognition, uncertainties about emissions from non-energy sources (e.g. biomass burning, vegetation, soil, ocean, non-vehicle mobile sources) at the global level are considerable (IPCC, 2001). This makes the development of a complete emission inventory a vital contribution to the successful study of global atmospheric chemistry and climate change (Jain et al., 2006). At local, national and regional scales, these inventories are also critical as they contribute to the achievement of the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC, 1992). In Ghana, an average of 68 ± 4 thousand km^2 of land is burnt annually; of this, 37 ± 2.6 thousand km^2 occur in the Northern region of Ghana. Approximately 53–56% of the total annual burnt land across Ghana occurs in the Northern region, which constitutes 29% of total dry land-cover of the country (Kugbe, 2012). This study aims at assessing the emission levels of CH_4 and CO from biomass burning in four different vegetation covers (based on the site level classification in Northern Ghana) and their implications for global warming.

2. Materials and Methods

2.1 Description and Location of the Study Area

This study was conducted in the Northern Region of Ghana (Figure 1), which has a population of about 2,468,557 (GSS, 2010). It lies within the Guinea Savanna Agro-Ecological Zone and forms part of the Volta Basin between the latitudes 8^o 30'N and 10^o 30'N and the longitudes 2^o 30'W and 0^o 00'W respectively. Characteristically, the area is characterized by two main seasons, wet and dry. The dry season starts in November and ends in April. The study site experiences a mono-modal rainfall pattern, which starts from May and ends in October. Within this period, rainfall peaks in August and September (Bagamsah, 2005). The mean monthly temperatures vary from about 36ºC in March/April to 27ºC in August. Relative humidity ranges between 20% and 85% (Cobbina et al., 2011). Approximately, 80% of the soils are upland soils developed in-situ from Voltaian sandstone and classified under the group of Lixisols (FAO, 1988). In general, the soils of the region have much lower organic matter content and nutrient status than those in the southern regions, thus the potential productivity of the soils of this zone may be regarded as being appreciably lower than that of the majority of the forest zone (Wills, 1962). The general vegetation of the study area is the mid-dry savanna type, with patches of dry woodland savanna and wet savanna (Menz and Bethke, 2000) that are classified as Guinea savanna (Lawson, 1985). Typically, the natural vegetation comprises a mix of tree (*Daniellia oliveri, Lophira spp, Terminalia glaucescens, Guiera senegalensis, Combretum glutinosum*, etc.) and grass (*Andropogon spp, Cymbopogon spp, Pennisetum spp,* and *Settaria spp, Aristida stipoides, Pennisetum spp,* and *Hyparrhenia spp)* species (Bagamsah, 2005). In terms of land use, northern Ghana is mostly utilized for agriculture and the typical crops cultivated include okra (*Abelemoschus esculentus*), groundnut (*Arachis hypogea*), tomato (*Lycopersicion esculantum)*, pepper (*Capsieum spp*), sweet potato (*Ipomoea batatas*), guinea corn (*Sorghum spp*), maize (*Zea Mays*), cowpeas (*Vigna spp*), cassava (*Manihot spp*) and yam (*Diascorea spp*.).

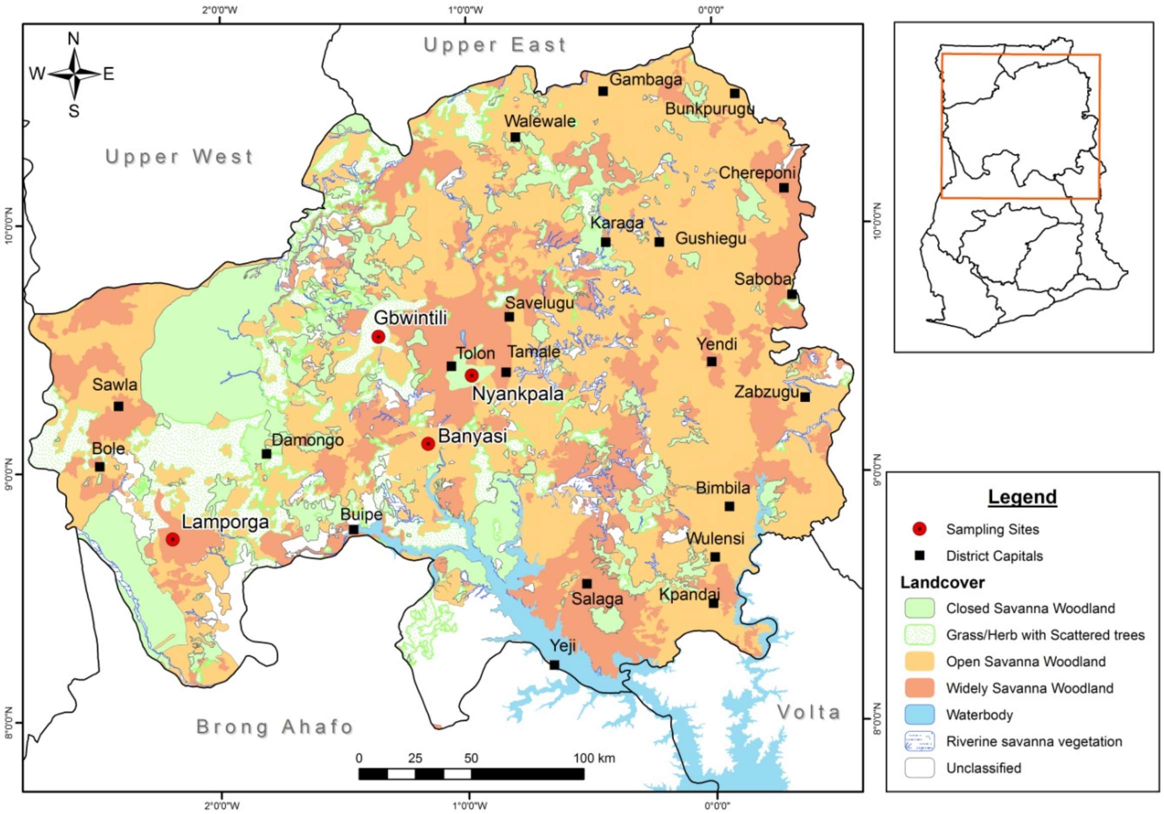

Figure 1. Map of the study area

Figure 2. The four vegetation types as classified by Bagamsah (2005). (**A**) Widely Open Savanna Woodland. (**B**) Mixture of grass/herb fallow with scattered trees and shrubs. (**C**) Open savanna woodland vegetation dominated by shrubs (OSW). (**D**) Closed savanna woodland (CSW)

2.2 Site Selection and Experimental Layout

Sampling was carried out within four different vegetation types (Figure 1); namely, widely open savanna woodland (WOSW), grass/herb with scattered trees (GHST), open savanna woodland (OSW) and closed savanna woodland (CSW), as classified by Bagamsah (2005). This classification was based on Dansereau's (1951) methodology for describing and recording vegetation on a structural basis. Figure 2 indicates the different vegetation types within which sampling were done. Using a GPS, a community was selected from each of the locations covered by the different vegetation types and they were used as experimental sites. The communities selected were Gwintili (GHST), Nyankpala (CSW), Banyasi (OSW) and Lamporga (WOSW). From each of these locations, samples of above-ground biomass (AGB) were collected from five randomly selected plots, each covering an area of $1m^2$ (Figure 3).

2.3 Determination of Carbon Content of Biomass Using the Combustion Furnace Method

The combustion furnace method used in this study was adopted from Benscoter et al. (2011).The biomass was dried to a constant dry mass for four days at a temperature of 65°C and milled thoroughly in a Cyclone Mill. Each crucible was weighed (W_1), filled with 5g of the milled biomass and weighed again (W_2). For ashing, the milled biomass and the crucibles were placed in a combusted muffle furnace carbolite at a temperature of 550 ºC for four hours and weighed again (W_3). Then the proportion (%) of organic carbon content was calculated using the following formulae:

$$\%\ \text{Ash} = \frac{W3-W1}{W2-W1} \text{ x } 100$$

% Organic matter = 100 - % Ash

$$\%\ \text{Organic carbon} = \frac{\%\ \text{Organic matter}}{2}$$

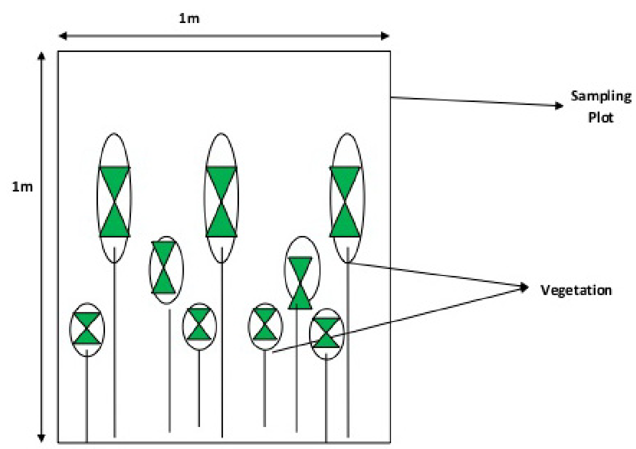

Figure 3. Schematic diagram showing experimental plot for sampling grass above-ground biomass

2.4 Estimating the Amount of Carbon Release, Methane and Carbon Monoxide Emitted by Biomass Burning

The carbon released from biomass burning in the study area was estimated using equations from the IPCC (1996) which involved the estimation of above-ground biomass density and carbon content in live and dead biomass. However, it must be noted that the estimated above-ground biomass density did not include standing trees; rather, the emphasis was on dried grass, litter, weeds and shrubs (Crutzen & Andreae, 1990). The default values used in the calculations were adopted from Hao et al. (1990) and Menaut et al. (1991). After quantifying the released carbon from the burnt savanna vegetation, emissions of CH_4 and CO were calculated and the emission ratios of CH_4 (0.004) and CO (0.06) from Lacaux et al. (1993) were adopted. The estimated emission values were subjected to statistical analysis at a confidence level of 95%. It is worthy of mention that the default values used in this study introduced some level of uncertainties into the estimation. However, the field and laboratory experiments carried out in the study reduced these uncertainties to an acceptable level. Additionally, the differences in biomass distribution across the study area made it difficult to accurately estimate the emitted carbon CH_4 and CO, so it is expected that there may be some degree of underestimation or overestimation of these values.

3. Result and Discussion

3.1 Grass Above-ground Biomass Density, Carbon Content and Total Carbon Emission

The estimated above-ground biomass density for the selected vegetation classes varied significantly at P<0.05. On the average, biomass density was highest on OSW with a density of ~4.8t/ha. This result is comparable to those obtained by other authors. For example, Saarnak et al., (2003) and Bagamsah (2005) reported a range of 3.36–7.80 t/ha and 2–3 t/ha respectively in northern Ghana; Shea et al. (1996) measured 3.7 t/ha in the savannas of South Africa, while Bourliére and Hardly (1983) reported 3.2–4.4 t / ha in the savannas of Cote d'Ivoire. Figure 4 shows the estimated above-ground biomass density for the different vegetation types.

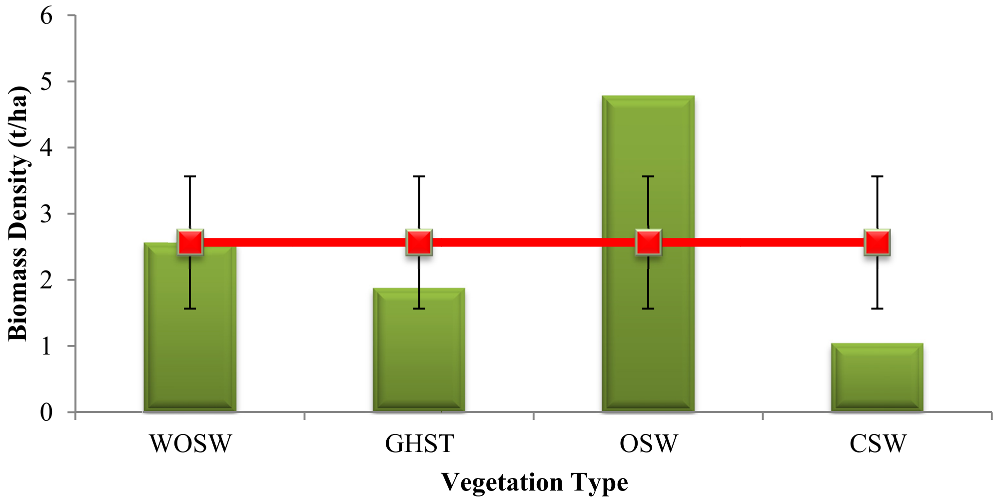

Figure 4. Estimated above-ground biomass density of grasses within the vegetation covers

Figure 5 shows that organic carbon content across the different vegetation types generally ranged from 29.3 % to 45.5%. On the average, GHST had the highest organic carbon content of 45.46%, while the least was CSW with 29.28% organic carbon content. The difference in the measured carbon content of the vegetation types was significant at P<0.05. Schlesinger (1991) noted that the carbon content of biomass is almost always found to be between 45% and 50%. With the exception of GHST, the carbon content of the other vegetation types fell below this range. Recent studies have shown that these assumptions introduce some degree of error of ~5% in forest carbon stock estimates (Martin & Thomas 2011; Thomas & Malczewski, 2007; Saner et al., 2012; Melson et al., 2011).

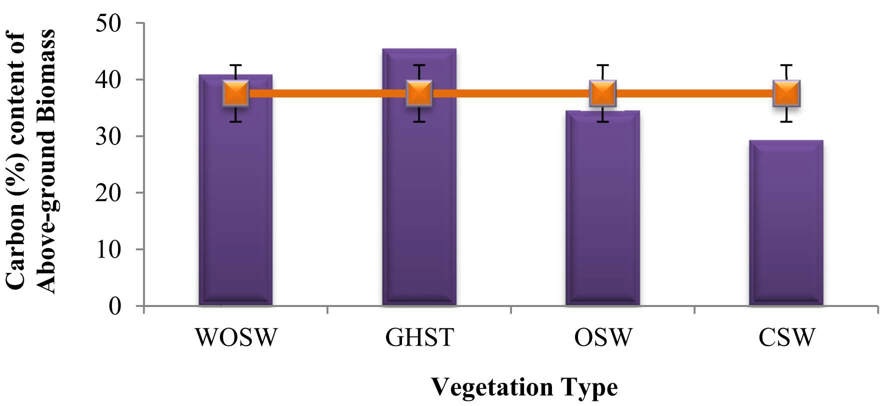

Figure 5. Estimated carbon content of grass above-ground biomass