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Research Article

Impacts of Anthropogenic Activities on Soil Nitrogen Store and Storage Potential in the Natural Forest-Savanna of Northern Ghana

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Abstract: This study has been conducted to assess the effects of anthropogenic activities on Nitrogen (N) store changes in soils and plants in the natural forest-savanna of northern Ghana. The study compared the N status of protected forests and adjacent unprotected forests which are prone to human activities (except farming and settlements). Three study zones (Wungu, Serigu and Mognori) were used for the research. A total of 96 composite soil samples (0-50 cm depth), 24 composite samples of above-ground live biomass and 24 composite samples of litter and root biomass were collected and analysed in the laboratory using standard procedures. The results showed that total plant N store i.e., N store in live biomass+litter+roots, was three times higher in the protected site than the unprotected in Wungu and Mognori and twice greater in Serigu. The observed variation between the two forest types was significant ($p<0.01$ and $p<0.05$) across the three study zones. Soil nitrogen store was significantly ($p<0.01$ and $p<0.05$) higher in all the protected sites than the unprotected across the three study zones. In general, soil N store was two times greater in the protected sites than the unprotected across the three study areas. The study demonstrates that proper monitoring and regulation of human activities across the off-reserve forests and existing forest reserves in the savanna ecological zone of northern Ghana is essential for maintaining adequate pools of nitrogen in soils and plants necessary for ensuring sustainable forest productivity and sustaining communities' livelihoods which are tremendously dependent upon the use of forest resources.

Keywords: Anthropogenic activities, forest-savanna, nitrogen store

INTRODUCTION

Global nutrient cycles have been greatly altered by land-use changes over the last century (Downing *et al*., 1999). Many studies suggest that human activities such as overexploitation, overgrazing and inappropriate clearing techniques have alterable effects on nitrogen cycle in ecological systems including savannas (Smil, 2000; Suddick *et al*., 2013). It is further established that tropical lands are subject to large losses of nutrient elements such as Nitrogen (N) or Phosphorus (P) (Ojima *et al*., 1994). Nitrogen is the major factor that controls the dynamics, biodiversity and functioning of many ecosystems (Vitousek *et al*., 1981). It plays a central role in limiting primary production in terrestrial ecosystems (Breman and de Wit, 1983). Deficiencies of other elements in the natural vegetation are usually only obvious once nitrogen and phosphorus constraints have been alleviated. The nitrogen cycle consists of various storage pools of nitrogen and processes by which the pools exchange nitrogen (Smil, 2000). Five main processes cycle nitrogen through the biosphere, atmosphere and geosphere: nitrogen fixation, nitrogen uptake (organismal growth), nitrogen mineralization (decay), nitrification and denitrification. Microorganisms, particularly bacteria, play major roles in all the principal nitrogen transformations (Vitousek *et al*., 1981). Hence rates are affected by environmental factors that influence microbial activity, such as temperature, moisture and resource availability (Smil, 2000). Deforestation causes increased losses of carbon, nitrogen, phosphorus and sulphur from terrestrial ecosystems (Vitousek *et al*., 1981). Losses of these elements following deforestation are most rapid in sites with high decomposition rates, especially in the tropics and on fertile soils. The major associated environmental concerns are:

- That plant growth on deforested sites will be slowed because of the nitrogen lost following deforestation.
- That the NO_x released during burning or the N_2O produced during nitrification or denitrification will adversely affect atmospheric chemistry (Crutzen, 1981).

- That nitrate leached to stream-water and ground-water could affect downstream ecosystems and even human health (Cooke *et al*., 1993).

Nitrogen cycling in undisturbed forests is relatively closed; the internal soil-plant-micro-organism cycle in most forests involves 10-30 times more nitrogen than annual nitrogen inputs or outputs (Rosswall, 1976) and annual inputs in aggrading forests generally exceed annual outputs (Likens *et al*., 1977). When this soil-plant-micro-organism cycle is disrupted by deforestation, however, a large fraction of the organic nitrogen present in an ecosystem can be lost. Deforestation interrupts the cycle both by preventing plant uptake of nitrogen and by increasing the rate of nitrogen mineralization (Vitousek and Melillo, 1979). The nitrogen cycle is dominated by mineralization of soil organic matter, which is in turn controlled by soil water content, soil temperature and the amount of readily mineralizable soil organic nitrogen present (Smil, 2000). Under natural conditions the content of organic matter in soil is constant; the rate of decomposition is equal to the rate of supply of organic matter from plants. The equilibrium is disturbed when forests are exposed to human pressures (Young, 1976). The conversion of forest land to other uses decreases above- and below-ground biomass on a site and leads to substantial decrease (well over 50%) in total organic matter (above and below ground, living and dead) (Vitousek *et al*., 1981). Hence, the soil carbon and nitrogen stores may increase or decreases depending on wether land-use practices are favourable or prohibitive to organic matter inputs in the soil (Zhou *et al*., 2006). Rapid forest losses are typical of all phases of disturbance in developing tropical nations (Salati *et al*., 1991). Over the past century tropical forests have been suffering from exceptional rates of change as they are degraded or destroyed by human activities. Approximately half of the tropical forest that was present at the beginning of the twentieth century has already disappeared, with peak deforestation in the 1980s and 1990s (Wright, 2005). Between 1960 and 1990, Africa and Latin America each lost about 18 percent of their tropical forest cover to deforestation (FAO, 2001). Approximately one-fifth of the world's population lives specifically within tropical regions consisting of savanna type vegetation. This results in large pressures being placed on savannas as a result of human activities (Schuttemeyer *et al*., 2006). Human activities such as overexploitation, overgrazing, inappropriate clearing techniques and unsuitable land-use practices are the major structuring forces in forest systems including savannas (Belsky and Blumenthal, 1997). The principal pathways of nitrogen loss from savanna ecosystems as a result of these human pressures are pyrodenitrification (Scholes and Walker 1993), herbivory (Belsky and Blumenthal, 1997) and logging (FAO, 2006). Anthropogenic fires in Africa are an ancient form of environmental disturbance, which probably have shaped the savanna forest more than any human induced disturbance (Sheuyange *et al*., 2005). Some estimates of gaseous N fluxes to the atmosphere from biomass burning in savannas are substantially too large (Menaut and Cesar, 1979). Hao *et al*. (1990) estimate that 3.69 Pg DM is consumed annually by fires in savannas, of which 2.43 Pg is in Africa. Fire in tropical grasslands and savannas (particularly in Africa) remains an important global source of N_2O and NO_x (Scholes and Hall, 1996). Emissions of N by fires are estimated at 11.4 Tg N yr-1 (5.4 kg N/ha/yr) in savannas and 5.3 Tg N/yr (3.8 kg N/ha/yr) in tropical forests, with these two biomes accounting for 75% of global fire N emissions (Chen *et al*., 2010). The net loss of atmospheric nitrogen from savanna ecosystems is largest in Africa, where fires burned more frequently than on other continents (Giglio *et al*., 2006). Net fire losses were equal to approximately 34% of biological N fixation (BNF) in savanna ecosystems in Africa, corresponding to 6.7 Tg N/yr or 5.7 kN/ha/yr in savanna ecosystems. Deposition from fires in African savannas offset only 26% of emissions to N. Considering N, deposition from fires was only 54% of emissions, indicating that African savannas were a net exporter of N to other ecosystems, including tropical forests in the Congo basin and the tropical Atlantic Ocean (Yang *et al*., 2009). Since tropical forests and savannas account for more than half of global terrestrial Net Primary Production (NPP) (Field *et al*., 1998) and may contribute substantially to contemporary (Stephens *et al*., 2007) and future land C sinks (Friedlingstein *et al*., 2006), it is important to quantify the processes contributing to changing levels of N and carbon storage in these ecosystems (Yang *et al*., 2009). Hence, assessing the extent to which differences in forest management practices impact on N store and storage potential in terrestrial ecosystems is essential for predicting the future alteration level of N stores associated with human-driven deforestation.

The forests in Ghana, which are part of the Guinea-Congoleanphyto geographical region, cover about 24.2% of the country's total land area of the country (FAO, 2010). Ecologically, the country is divided into a high forest zone to the southwest, accounting for about a third of the land area (about 7.5 million hectares), a savanna zone (14.7 million hectares) mostly in the north and a transition zone (1.1 million hectares) (ITTO, 2006). In Ghana, increasing evidence indicates that the rate of environmental degradation has increased in recent times (Gyasi *et al*., 1995), with previously rich forests being converted to savanna woodland and existing savanna woodlands converted into near desert (Hawthorne and Abu-Juam, 1995). The total conserved area which is about 15 million hectares is under huge anthropogenic pressure as it is estimated that 20, 000 hectares per annum of this reserved area is lost to

agriculture, or through bush fires and other human activities (Siaw, 1998). Hence, if the present trend continues, most parts of Northern Ghana will easily become desert (Siaw, 1998). The unrelenting human pressure put on forest resource across the savanna ecological zone of northern Ghana constitutes therefore a serious threat to the important roles played by the forest-savanna ecosystem in servicing the ecological environment and socio-economics of the region (Nsiah-Gyabaah, 1996). It is widely established that the human-driven progression of tropical forest, from pristine to highly altered forest stands is likely to result in a predictable sequence of changes to N exports; and that this would be characterized by (1) an initial pulse in N exports via leaching and erosion upon cutting of mature forests and other vegetation and (2) a second pulse in N exports via leaching and erosion upon burning (Downing *et al*., 1999). Hence, human activities across the forest-savanna of northern Ghana could have the potential to alter the nitrogen stores of this forest ecosystem and adversely affect its sustainable productivity and conservation. This situation could take a heavy toll on communities' livelihoods as forest resource makes an important tangible contribution to the quality of community and individual life (Francois, 1995). The preservation and conservation of the forest-savanna of northern Ghana is therefore essential for maintaining its ecological balance and ensuring sustenance of communities' livelihoods. Hence, rehabilitation and conservation are a matter of priorities and should be followed by an in-depth assessment of the state of health of this forest ecosystem (Leach and Fairhead, 2000; Wardell *et al*., 2003). It is against this backdrop that the present research was carried out. The relevance of this study is further bolstered by the fact that there is little published information on the human-induced biogeochemical degradations, especially the Nitrogen (N) biogeochemistry alteration that the forest-savanna of northern Ghana is undergoing. Hence, the objective of the study was to assess the extent to which human activities have altered N cycling in the forest-savanna of northern Ghana by comparing N stores in the soils and plants under protected forests and adjacent

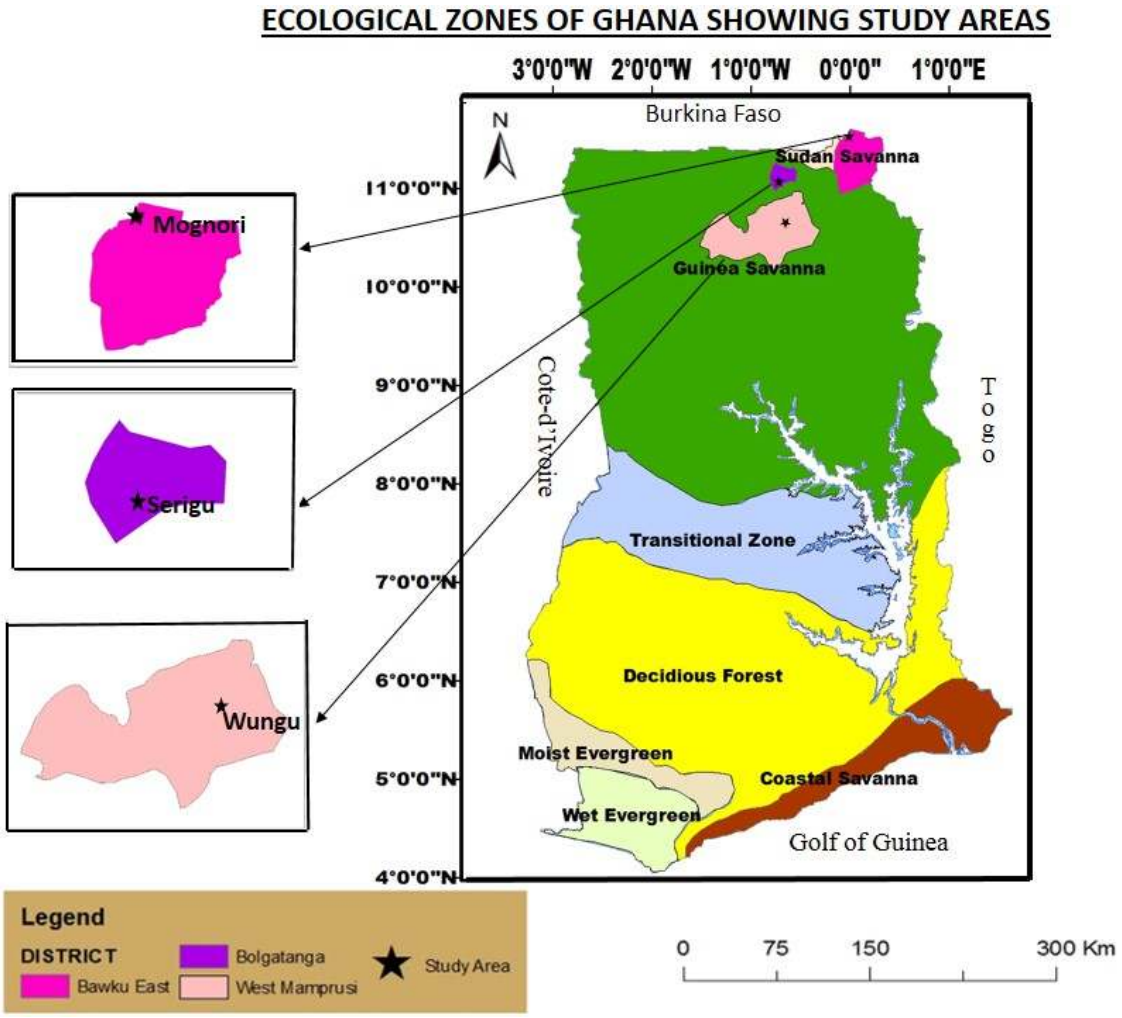

Fig. 1: Map of Ghana showing the location of study areas

unprotected forests which are prone to human activities (except farming and settlements).

MATERIALS AND METHODS

Description of the study area: The study was conducted in the savanna ecological zone in northern Ghana (8°N, to lat. 11° N and longitudes 2°57'W and 0°34'E) (Fig. 1). The climate in this area is characterised generally as tropical continental, or savanna, with a single rainy season, from May to October, followed by a prolonged dry season (Siaw, 1998). Average ambient temperatures are high year round (about 28^{o}C) but the harmattan months of December and January are characterised by minimum temperatures that may fall to 13^{o}C at night, while March and April may experience 40^{o}C in the early afternoon. The area is associated with a total annual rainfall of about 1000-1300 mm/annum. The rainy season is 140-190 days in duration, while the estimated reference evaporation is about 2000 mm/annum, creating a great seasonal deficit every dry season. The peak rainfall period is usually late August or early September. About 60% of the rainfall occurs within the three months (July to September).

Most of the geological formations in the area are overlain by a regolith comprising in situ chemically weathered material and, to a lesser extent, transported surface material. Typically, this weathered layer consists (from top to bottom) of a residual soil zone (usually sandy-clayey material possibly underlain by an indurated layer) and a saprolite zone (completely too slightly decomposed rock with decreasing clay content with depth) (Carrier *et al*., 2008).

The vegetation cover typical of northern Ghana consists of mixed formations of fire resistant trees and shrubs. Moving northwards, within the savanna region, there is at first densely wooded and vigorous grassland (*Andropogon, spp.)* with fire resistant shrubs, often referred to as woodland savanna or Guinea savanna. Further north, in an increasingly arid environment, grass savanna or sudan savanna is formed, with trees and shrubs either absent or very sparse (Siaw, 1998). The total conserved of the northern Ghana savanna area is about 15 million hectares. The reserved forest which was established by the Forest Ordinance of 1910 (Francois, 1995) is made up of 11, 590 km² of production forests, 4,323 km² of protection forests and about 1,980 km² of game production reserves. It is estimated that 20,000 hectares per annum of the reserved area is lost to agriculture, or through bush fires and other human activities such as bush burning, overgrazing, logging and mining (FAO, 1998). The persistent exposure of this forest ecosystem to human activities constitutes a serious threat to its sustainability and communities' livelihoods (Campbell *et al*., 2000; Siaw, 1998).

Site selection and plot demarcation: Three study zones (Wungu, Serigu, Mognori) were used for the comparative study. Each zone was made up of two neighbouring forest types, namely the protected (a forest reserve or sacred grove) and unprotected types. The selection of the study zones was effected based on the distinct ecologies which can be distinguished within the interior savanna and the level of protection and exposure to human activities of the protected and unprotected forest sites respectively. The unprotected sites have continuously been subjected to human activities (except farming and settlements) whilst the forest reserves and sacred groves have been well monitored and kept off from human disturbances. The effective monitoring and protection of the forest reserves and sacred groves represents an ideal opportunity to study the effects caused by forest sites long-term exposure to human pressures in the savanna ecological zone of northern Ghana. The study areas were named as follows: WP (Wungu protected forest) and WU (Wungu unprotected forest) for Wungu study site, SP (Serigu protected forest) and SU (Serigu unprotected forest) for Serigu study site, MP (Mognori protected forest) and MU (Mognori unprotected forest) for Mognori study site.

Four 30×30 m random plots were set in both the protected and neighbouring unprotected forest sites of each study zone in late August (late peak rainy season) and used for biomass and soil sampling.

Above and Below-ground herbaceous plant biomass was harvested from within four 1×1m random subplots of each 30×30 m study plots across the three study zones. The biomass sampling was carried out in late August at both sites in all the three study zones, at the time when most grasses had reached their maximum growth (peak biomass) after which senescence starts (Sala and Austin, 2000). The above ground herbaceous plant biomass was collected by clip harvesting all the living tissues of grasses (leaves, stems, inflorescences and fruits produced in a single year) from the ground surface that occurred in each 1×1 m random subplot of each study plot. Litter was collected from within each 1×1 m subplots of each study plot after the above ground biomass was harvested. Root biomass was collected by soil coring method to 20 cm diameter and 20 cm depth from all the four 1×1 m subplots on each 30×30 m plot demarcated for biomass sampling. Soil samples were collected from within all the four 1×1 m random subplots of each 30×30 m plot by soil coring method using a -5 cm diameter soil core sampler to 50 cm depth and separated into 10 cm layers (0 - 10, 10 - 20, 20- 30, 30- 40, 40- 50 cm). Soil and biomass sampling were conducted concomitantly in all the three study zones.

Harvests consisted of a total of 96 composite soil samples (0-50 cm depth), 24 composite samples of above-ground live biomass and the same number of

litter and root biomass samples. The collected samples were used to make composite samples for the determination of N stores in plant and soil materials.

Soil and plant samples preparation and laboratory analyses: Plant materials samples were rid of all debris, weighed to determine the gross weight and air- dried in a ventilated room. Roots were washed and separated from the soil efficiently (Motsara and Roy, 2008). 100 g of each component were subsequently sampled and oven-dried at 70°C to a constant weight to determine the percentage of water content so as to convert material from field (green) weight to dry weight.

All soil samples were spread on a drying tray to remove roots and other debris and air-dried for 3 days and ground with a wooden pestle and mortar to loosen the aggregates. After grinding, the soil was screened through a 2-m mesh and mixed thoroughly. The prepared samples were then stored in labelled bags and taken to the laboratory for the necessary chemical analyses. Soil and plant nitrogen contents were estimated using the modified kjeldahl digestion method (Motsara and Roy, 2008). The residue NH_4-N was titrated with standardized H_2SO_4.

Method of calculation of N store in Above-ground Live Biomass (ALB): Nitrogen store in above-ground live biomass (in grams per square meter) was determined using the following formula:

$$N_{ALB}\,(g/m^2) = \frac{\text{Dry weight of above-groung live biomass}\left(\frac{g}{m^2}\right) \text{ X \% N content in live biomass}}{100}$$

Method of calculation of N store in litter: Nitrogen store in litter (in grams per square meter) was determined as follows:

$$N_{\text{Litter}}\,(g/m^2) = \frac{\text{Dry weight of litter biomass}\left(\frac{g}{m^2}\right) \text{ X \% N content in litter}}{100}$$

Method of calculation of N store in roots: Nitrogen store in roots (in grams per square meter) was determined as follows: The amount of N in a root core of 20 cm diameter and 20 cm depth is N_r (g) $= \frac{\text{\% N in roots X total mass of dry roots}}{100}$ corresponding to an area of 3.14 X $(\frac{20}{2})^2$ Cm^2 or 314 X $10^{-4}m^2$. For an area of 1 m^2 N store (g/m^2) = N_r X $10^4 m^2$/ 314.

Method of calculation of N store in soil: Soil Total N store ($STN_{store}(g/m^2)$) was estimated using the following formula: $STN_{store}(g/m^2)$ = $SN_{density}$ X S X d.

Where, $SN_{density}$, S and d represent the soil nitrogen density, the total area interested and the soil depth (50 cm) respectively. $SN_{density}$ = N X BD.

Where, N is soil nitrogen average content (g/kg), BD is the bulk density of soil (gcm^{-3}) at a 50 cm depth.

Statistical analyses of data: The results were subjected to analysis of variances (ANOVA) using the software programme SPSS, ver. 16.0 (SPSS Inc., Chicago, IL, USA) to determine treatment effects (i.e. protected versus unprotected forests) for each study zone on collected data. The Least Significant Difference (LSD) test was employed to compare the means for each study zone at 0.05 and 0.01 significance levels.

RESULTS AND DISCUSSION

General findings: Nitrogen store in total above-ground biomass i.e. live plus litter biomass was three times higher in the protected site than the unprotected in Wungu and Serigu and twice greater in Mognori (Table 1). Differences in above-ground biomass N store between the two forest types were significant ($p<0.01$) in Wungu and Serigu, as opposed to Mognori where no significant difference ($p>0.05$) was recorded between the treatment and control sites (Table 2). The data also showed that N store in roots was significantly ($p<0.01$) higher in the protected sites than the unprotected in Wungu and Mognori. However, no significant difference ($p>0.05$) in nitrogen store in roots was recorded between the two forest types in Serigu (Table 2). Nitrogen store in roots was three times higher in WP than WU, four times greater in MP than MU and slightly greater in SP than SU (Table 1). Total plant N store i.e. N store in live biomass+litter+roots, was three times higher in the protected site than the unprotected in Wungu and Mognori and twice greater in SP than SU (Table 1). The observed variation in Total plant N store between the two forest types was significant ($p<0.01$ and $p<0.05$) across the three study zones (Table 2). The study results further showed that the pattern of variation in N stores in the three components of plant biomass i.e. live, litter and roots biomass, between the protected and unprotected forests was similar in Wungu and Mognori, as opposed to Serigu. While in Wungu and Mognori, roots and live biomass were the most variable, in Serigu, litter showed the highest variability (Table 1).

Soil nitrogen store was significantly ($p<0.01$ and $p<0.05$) higher in all the protected sites than the unprotected across the three study zones (Table 1 and 2). In general, soil N store was two times greater in the protected sites than the unprotected across the three study areas. Among all the three study zones, Wungu had by far the least variation (277 g Nm^{-2}) between the protected and unprotected forests. The variation in soil

Table 1: Effect of forest management type on total amounts of nitrogen (g/m^2) stored in soil and plant pools

Forest management system		
Ecosystem components	Protected forest	Unprotected forest
Above-ground N	WP	WU
Live Biomass N	7±3	2±1
Dead biomass (Litter) N	2±2	1±1
Total Above-ground N	9±3	3±1
Total Roots N		
0-20 cm	0±3	3±1
Total Plant N	19±3	6±1
Soil organic N (0-50 cm)	895±3	618±32
Above-ground N	SP	SU
Live Biomass N	4±2	2±1
Dead Biomass (Litter) N	3±1	0.2±1
Total Above-ground N	7±2	2.2 ±1
Total Roots N		
0-20 cm	4±1	3±1
Total Plant N	11±1	5.2 ±1
Soil organic N (0-50 cm)	1479±100	695±158
Above-ground N	MP	MU
Live Biomass N	1±1	1±1
Dead Biomass (Litter) N	1±1	0.1±1
Total Above-ground N	2±1	1.1±1
Total Roots N		
0-20 cm	4 ±1	13±1
Total plant N	11±1	5.2±1
Soil organic N (0-50 cm)	1479 ±100	695±158
Above-ground N	MP	MU
Live Biomass N	1±1	1±1
Dead Biomass (Litter) N	1±1	0.1±1
Total Above-ground N	2±1	1.1±1
Total Roots N		
0-20 cm	8±4	2±1
Total Plant N	10±3	3.1±1
Soil organic N (0-50 cm)	1372±75	764±106

Within rows, means±S.D. (n = 4)

Table 2: Summary of the analysis of variance (ANOVA) outputs of nitrogen store in soil and plant between protected and unprotected forest sites at each study zone

Ecosystem component	F-Value	p-Value	Outcome	Level of variance
Nitrogen store in live biomass				
Wungu	27.541	0.001	p< 0.01	Significant
Serigu	5.690	0.054	p> 0.05	Not significant
Mognori	1.208	0.313	p> 0.05	Not significant
Nitrogen store in litter				
Wungu	2.839	0.142	p> 0.05	Not significant
Serigu	54.615	0.000	p< 0.01	Significant
Mognori	28.146	0.001	p< 0.01	Significant
Nitrogen Store in Root Biomass				
Wungu	35.563	0.000	p< 0.01	Significant
Serigu	54.615	0.000	p< 0.01	Significant
Mognori	74.216	0.000	p< 0.01	Significant
Nitrogen Store in total above-ground Biomass				
Wungu	8.928	0.009	p< 0.01	Significant
Serigu	14.562	0.001	p< 0.01	Significant
Mognori	3.827	0.07	p> 0.05	Not significant
Total plant nitrogen store				
Wungu	18.352	0.000	p< 0.01	Significant
Serigu	11.323	0.002	p< 0.01	Significant
Mognori	5.094	0.034	p< 0.05	Significant
Soil nitrogen store				
Wungu	1940.34	0.000	p<0.01	Significant
Serigu	48.8590	0.000	p<0.01	Significant
Mognori	8.23600	0.028	p<0.05	Significant

N values between the protected and unprotected forests showed the following rank order across the three study zones: Serigu (784 g Nm^{-2}) >Mognori (608 g Nm^{-2}) >Wungu (277 g Nm^{-2}) (Table 1).

DISCUSSION

Anthropogenic activities in terms of bushfires, overgrazing and logging influence nitrogen cycling in tropical ecosystems and thereby affect the organization and functioning of these ecosystems because nitrogen availability is a key factor controlling the nature and diversity of plant life and vital ecological processes such as plant productivity and the cycling of carbon and soil minerals (Vitousek *et al*., 1997). It is further established (Field *et al*., 1998) that since tropical forests and savannas account for more than half of global terrestrial Net Primary Production (NPP) and may contribute substantially to contemporary (Stephens *et al*., 2007) and future land C sinks (Friedlingstein *et al*., 2006), it is important to quantify the impacts of human induced pressures on N cycling and carbon storage in these ecosystems. In this study, we assessed the extent to which human activities affect N cycling in the in the natural forest-savanna of northern Ghana by comparing the soil N stores of protected forests and adjacent unprotected forests which are prone to human activities (except farming and settlements). The observed differences in N stores in soils, above-ground biomass and root biomass between the protected and unprotected sites across the three study zones suggest that the nitrogen stores and storage conditions in soil and plants were significantly affected by human activities in the natural forest-savanna zones. These findings are substantiated by previous authors who reported that when the soil–plant–micro-organism cycle of nitrogen is disrupted by deforestation a large fraction of the organic nitrogen present in an ecosystem can be lost (Vitousek and Melillo, 1979). The decrease in N pools in both soil and plants under unprotected forests could be explained by the gradual decrease in the inputs of organic matter in the soils and low nutrients cycling as a result of the continued removal of plant biomass through human activities. It is indeed established that the nitrogen cycle is dominated by mineralization of soil organic matter, which is in turn is controlled by soil water content, soil temperature and the amount of readily mineralizable soil organic nitrogen present (Tiessen *et al*., 1994; Smil, 2000). From the study results it could be concluded that anthropogenic activities have the potential to alter N and other nutrients cycle and N pools in soil and plants in the forest-savanna of northern Ghana and consequently influence the production of biomass and the functioning of this forest ecosystem as nitrogen and phosphorus are the two most needed nutrients in greatest quantities for plant growth (Lambers and Poorter, 1992; van der Werf *et al*., 1993). Hence, the unrelenting human pressure on off-reserve forests and continued encroachments on forest reserves could result in drastic reduction in forage availability for livestock production in the region; more so as livestock production is an important feature of the agricultural economy in the savanna zones (Aweto and Adejumobi, 1991) and as savannas in Africa are largely exploited through livestock grazing (Bilotta *et al*., 2007). It is indeed established (Asafu-Adjei and Dantankwa, 2001) that the major production of livestock in Ghana is concentrated in the Northern, Upper East and Upper West regions where the vegetation is sudan savanna and guinea savanna type. Besides, according to the same authors, these three regions account for up to 77% of cattle production in the country. Moreover, this sub-sector is estimated to contribute about 9% to the nation's agricultural Gross Domestic Product (GDP) and is a source of income for several rural farm households, especially in the northern part of the country (Asafu-Adjei and Dantankwa, 2001).

CONCLUSION

The study findings show that anthropogenic activities have alterable effects on nitrogen cycle in the natural forest-savanna of northern Ghana. The study therefore emphasises the need to monitor and regulate the ongoing human activities across the forest-savanna of northern Ghana so as to ensure proper cycling of N and other nutrients in the soils under this forest ecosystem and maintain adequate nitrogen store and soil fertility necessary for sustainable forest productivity and livestock production in the region. Besides, forest management prescriptions in the savanna ecological zone should be vigorously supported by an efficient and effective implementation of the intensive national livestock production policy in the country as livestock production system in Ghana is still based mainly on extensive grazing (Asafu-Adjei and Dantankwa, 2001). Such measures would greatly contribute to alleviating the pressure put on off-reserve forests and indeed reduce encroachments on forest reserves besides sustaining the socioeconomic development of the region. For it is established that poverty is highly concentrated in rural areas in Ghana, particularly in the savanna ecological zone; and that forest products are an important resource in the livelihood systems of many rural households and communities in northern Ghana (NSBC, 2002).

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