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Impacts of anthropogenic activities on physical and selected chemical properties of soils in the natural forest-savanna of Northern Ghana

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This study assessed the impacts of anthropogenic activities on the textural and selected chemical properties of the soils in the natural forest-savanna in northern Ghana by comparing the soil physicochemical status of protected forests and neighbouring unprotected forests which are prone to human pressures (except farming and settlements). Three study zones (Wungu, Serigu, and Mognori, which are parts of West Mamprusi, Bolgatanga and Bawku East Districts respectively) were used for the study. Ninety-six (96) composite soil samples (0-50 cm depth) were collected for analysis. The study results showed that the texture of soils generally showed little difference between the protected and unprotected forests within each study zone. Bulk density, Cation exchange capacity (CEC), and soil organic C, Total Nitrogen (TN), and phosphorus (P), values were generally higher in the protected sites than the unprotected. Exchangeable bases (Ca, Mg, K and Na) and available micronutrients (Fe, Mn, Zn and Cu) content were greater in the protected forests than the unprotected. The study therefore suggests the development of management systems for off-reserve forests in a direction which protects the fertility of the soils under these forests, and sustains forest productivity and people's livelihoods.

Key words: Forest-savanna, soil, physicochemical properties, soil health and fertility.

INTRODUCTION

Forests play an important role in protecting the soil, water resources and ameliorating the environment (FAO, 2002). Forest soils in particular play a vital role in determining the sustainable productivity of the forest ecosystems (Kumar and Babel, 2011). Therefore, soil fertility changes and the nutrient balances are taken as key indicators of forest ecosystem quality (Jansen et al., 1995). Hence, forest lands with good physical and chemical characteristics are essential in maintaining productivity in terrestrial ecosystems and driving processes that maintain environmental quality (Moussa et al., 2008) and sustainability (Hopmans et al., 2005; Liebig et al., 2006). At present, forest is a threatened natural resource. Anthropogenic activities such as overexploitation, over-grazing, inappropriate clearing techniques and unsuitable land-use practices have resulted in severe soil nutrient

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decline and decrease in productivity (ISRIC, 2007). It is further widely established that, human activities are increasingly altering the ways in which energy and elements cycle within and move between ecosystems including forests (Houghton et al., 1999; Jing-wei et al., 2011). Human-driven deforestation causes increased losses of carbon, nitrogen, phosphorus, and sulphur from terrestrial ecosystems. Losses of these elements following deforestation are most rapid in sites with high decomposition rates, especially in the tropics and on fertile soils (Vitousek et al., 1981). Over the past century tropical forests have been suffering from exceptional rates of change as they are degraded or destroyed by human activities (Wright, 2005). Approximately one-fifth of the world's population lives specifically within tropical regions consisting of savanna type vegetation (Schuttemeyer et al., 2006). Savannas occupy about 20% of the land surface of the world, and about 40% of Africa (Scholes and Walker, 1993). In Ghana, as in many areas in Africa, savanna woodlands provide valuable environmental services, are a critical refuge for native biodiversity, and also protect soil and water resources against degradation. With about 20% of the national population the northern and coastal savanna zones supply about 70% of Ghana's total supply of firewood and charcoal, estimated at 16 million cubic meter, and also provides medicinal plants, thatches, fencing poles, and fruits (e.g., shea-nut which is an increasingly important export commodity) (NSBC, 2002). However, while the pursuit of economic and social exploitation of forest resources has contributed to development in both rural and urban communities in the country, the manner in which it has sometimes been done has led to decline in forest environmental quality (Francois, 1995). As a result, the forest-savanna of northern Ghana continues to experience major biophysical environmental degradations closely associated with such activities as commercial and artisanal logging, large scale land conversion, fuel wood and charcoal production, slash and burn agriculture, grazing, harvesting of non-timber forest products, hunting and mining (Nsiah-Gyabaah, 1996; FAO, 2000). Hence, the preservation and conservation of this forest ecosystem is of paramount importance not just for the sake of production of commodities, but more so for maintaining its ecological balance and environmental reasons. An in-depth assessment and understanding of the extent and nature of the human-induced effects on the soil physicochemical properties of the forest-savanna of northern Ghana will therefore be a valuable tool in developing effective conservation mechanisms and ensuring long-term productivity of this forest ecosystem. This perspective further finds its relevance in the fact that there is a paucity of published information on the effects of human activities on the northern Ghanaian forest-savanna ecosystem variability. It is against this background that the current study was conducted. The objective of the study was to assess the induced effects of human activities on soil textural and selected chemical properties by comparing the physicochemical status of the soils under protected forests and neighbouring 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 latitude 11°N and longitudes 2°57'W and 0°34'E) (Figure 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 (FAO, 1998). Average ambient temperatures are high year round (about 28°C) but the harmattan months of December and January are characterized by minimum temperatures that may fall to 13°C at night, while March and April may experience 40°C in the early afternoon. The area is associated with a total annual rainfall of about 1000 to 1300 mm per annum. The rainy season is 140 to 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, that is, from July to September.

Most of the geological formations in this 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 to slightly decomposed rock with decreasing clay content with depth) (Carrier et al., 2008). The soils of the study zones include Gleyic Lixisols (Bolgatanga District), Savanna Ochrosols (Bawku East District) and Savannah Gleisols which are found in West Mamprusi District (Jessica and Pablo, 2001; GSS, 2014; CEPA, 2000)

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 (FAO, 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 ha per annum of the reserved area is lost to agriculture, or through bush fires and other human activities such as bush burning, overgrazing, and mining coupled with over exploitation of plants by people in the form of fuel wood and charcoal, timber and medicinal products (FAO, 1998). The persistent exposure of this forest ecosystem to human activities constitutes a serious threat to its environmental sustainability and communities' livelihoods (Francois, 1995; FAO, 1998; Campbell et al., 2000).

Site selection and sampling

Three study zones (Wungu, Serigu, Mognori) were used for the comparative study. Each zone was made up of two neighbouring

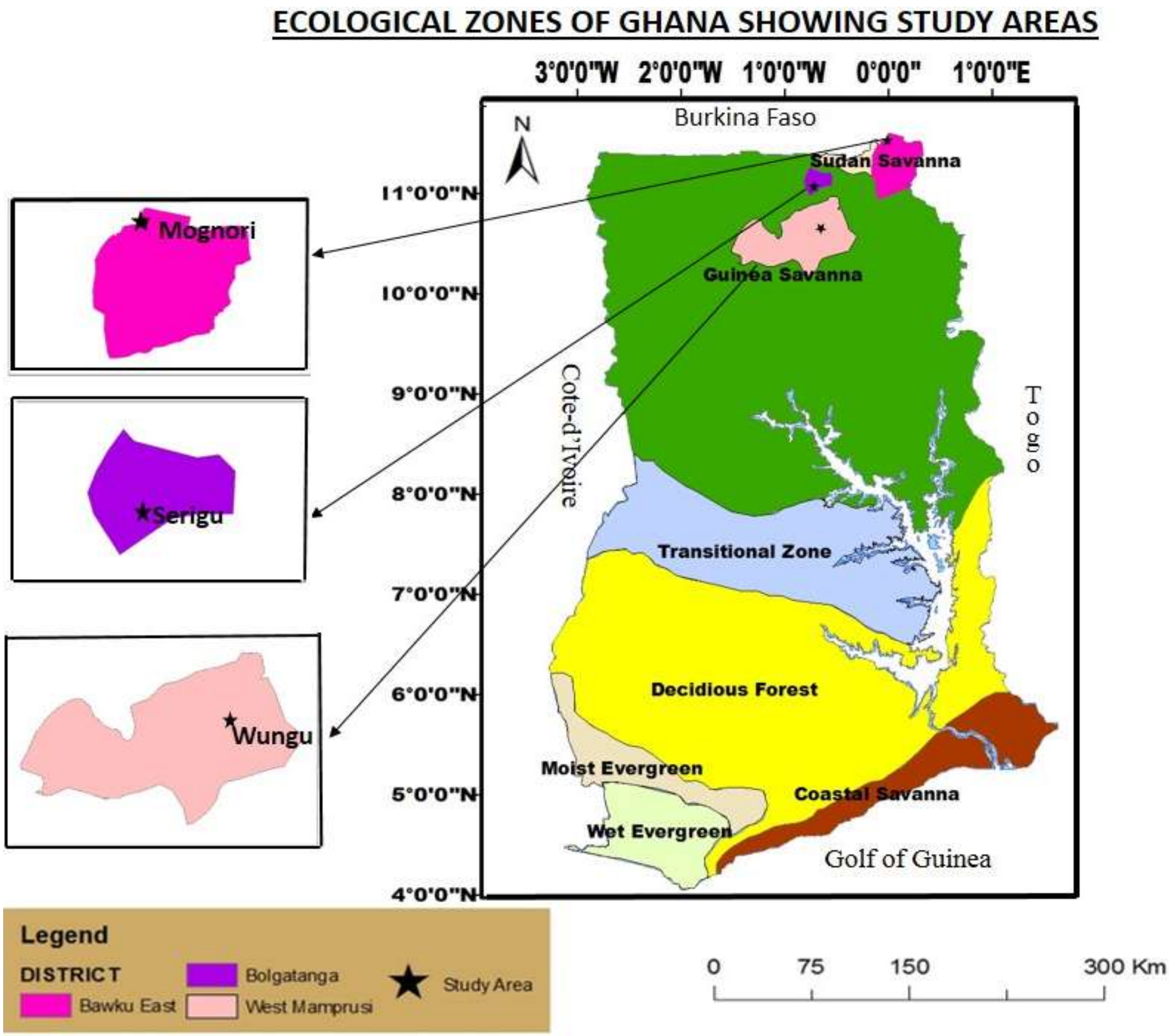

Figure 1. Map of Ghana showing the location of study areas.

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 m × 30 m random plots were set in both the protected and neighbouring unprotected forest sites of each study zone in late August 2013 (late peak rainy season) and used for the soil sampling. Soil samples were collected from within all the four 1 × 1 m random subplots of each 30 × 30 m plot using soil coring method to 50 cm depth and separated into 10 cm layers (0 - 10, 10 - 20, 20- 30, 30- 40, 40- 50 cm). A total of 160 random soil samples (0-50 cm depth), were collected in both adjacent forest types of each study zone to make composite samples for the determination of selected physical and chemical properties.

Soil samples preparation and laboratory analyses

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-mm mesh and mixed thoroughly. The prepared samples were taken to the laboratory and analysed for the

Table 1. Methods of analysis of soil physicochemical properties.

S/N	Properties	Procedure	References
A	Mechanical analysis	Hydrometer method	Bouyoucos (1962)
B	Physico-chemical characteristics		
1	Organic carbon	Walkley and Black's wet digestion method	Motsara and Roy (2008)
2	Cation Exchange Capacity	1M NH_4OAc method estimated on flame photometer	Motsara and Roy (2008)
3	pH(1:1 Soil water suspension)	Glass electrode pH meter	Van Lierop (1990)
4	Macronutrients		
4.1	Total Nitrogen (N)	Modified Kjeldahl method using salicylic acid	Subbiah and Asija (1956)
4.2	Available Phosphorous (P)	Bray's method No.1 estimated on AAS	Olsen et al. (1954)
4.3	Available Potassium (K)	1M NH_4OAc method estimated on flame photometer	Page et al. (1982)
5.1	Available micronutrients : Zn, Fe, Cu and Mn	DTPA extract estimated on AAS	Lindsay and Norvell (1978)

determination of available macronutrients and micronutrients. Standard analytical methods were used in the analysis of soil samples (Table 1).

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 (that is, 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

Effects of human activities on soil physical properties

The textural analysis indicates that the soils have relatively high sand and low clay contents in Wungu and Serigu, and high silt and clay contents in Mognori in both the protected and unprotected forest sites (Table 2). Unlike in Mognori study site where the clay content was twice greater in the unprotected site than the protected, the difference in clay content between the two forest types was minute in Serigu and Wungu. Besides, the observed differences between the two forest types were only significant in Mognori ($P< 0.05$) in contrast to Wungu and Serigu sites where no significant difference ($P> 0.05$) was observed. The silt content was higher in the protected site than the unprotected in Serigu and Mognori as opposed to Wungu where the silt content was higher in the unprotected site (Table 2). The variation in silt content between the two forest types was significant in Wungu ($P< 0.01$) and Serigu ($P< 0.05$) while no significance ($P > 0.05$) difference was recorded in Mognori. Expect for Serigu site where the sand content was higher in the unprotected site, in Wungu and Mognori the sand content was higher in the protected site. The recorded difference in the sand content between the two forest types was significant in Wungu and Serigu ($P< 0.05$) as opposed to Mognori where there was no significant difference ($P > 0.05$). Soil bulk density (BD) values were significantly ($P< 0.01$) higher in the unprotected forest sites than the unprotected across the three study zones (Table 2). According to bulk density rating suggested by Batjes (1996), BD values ranked low ($b ≤ 1.35$ g/cm^3) across the protected sites in contrast to the unprotected forest sites which recorded high bulk density values ($1.35< b ≤ 1.55$ g/cm^3).

Effects of human activities on selected chemical properties

Soil pH, organic matter, organic carbon, total nitrogen, and available phosphorus

Except for Mognori site, soil pH values were generally higher in the protected sites than the unprotected (Table 3). However the magnitude of the observed differences in pH between the two forest types varied across the study zones. According to classification of soil pH suggested by Hazelton and Murphy (2007), the soil pH was moderately acid (pH 5.9) in WU, and neutral in WP (pH 6.7) and SU (pH 6.8), and mildly alkaline in SP (pH = 7.5), MP (pH = 7.2), and MU (pH = 7.5). Except for Mognori site where no significant ($P> 0.05$) difference in pH was observed between the two forest types, the variation in pH values between the protected and unprotected sites was significant in Wungu ($P< 0.01$) and Serigu ($P< 0.05$).

Results in Table 3 further show that soil organic matter contents ranged from good to medium (Tekalign, 1991) across the protected sites; with values ranging from 2.6, 4.8, and 4.44% in WP, SP and MP respectively. By contrast, organic matter contents were generally ranked low across the unprotected sites as values ranged from 1.5, 1.82, and 1.70 in WU, SU, and MU respectively. Soil organic matter was twice higher in WP than the unprotected and three times greater in SP and MP. The differences in soil organic matter contents between the

Table 2. Mean values of particle size distribution as affected by forest management type.

Forest type	% Sand	% Silt	% Clay	Texture	BD (gcm^{-3})
WP	73.15 ± 1.53	24.82 ± 1.52	2.03 ± 0.02	Loamy sand	1.38 ± 0.00
WU	56.12 ± 8.61	40.85 ± 8.22	3.03 ± 1.14	Sandy loam	1.46 ± 0.02
SP	58.93 ± 3.27	38.39 ± 2.52	2.68 ± 0.95	Sandy loam	1.22 ± 0.02
SU	71.26 ± 7.43	26.28 ± 6.72	2.53 ± 1.01	Loamy sand	1.43 ± 0.04
MP	28.32 ± 25.14	62.68 ± 26.00	9.01 ± 3.84	Silty loam	1.22 ± 0.10
MU	22.89 ± 1.18	57.09 ± 1.17	20.02 ± 0.02	Silty loam	1.44 ± 0.02

Within rows, means ± S.D., n = 4.

Table 3. Mean values of pH, organic matter (OM), organic carbon (OC) total nitrogen, and available phosphorus as affected by forest management type

Forest type	pH (1:1H_2O)	OM (%)	OC (%)	Total N (%)	Available P (mg/kg)
WP	6.7 ± 0.52	2.60 ± 0.07	1.50 ± 0.04	0.13 ± 0.00	9.57 ± 4
WU	5.9 ± 0.21	1.50 ± 0.11	0.87 ± 0.06	0.09 ± 0.01	2.45 ± 1
SP	7.5 ± 0.34	4.80±0.61	2.78 ± 0.35	0.24 ± 0.032	23 ± 15
SU	6.8 ± 2.33	1.82 ± 0.45	1.06 ± 0.26	0.1 ± 0.025	6 ± 1
MP	7.2 ± 0.47	4.44 ± 1.31	2.60 ± 0.76	0.23 ± 0.07	11.61 ± 10
MU	7.5 ± 0.29	1.70 ± 0.48	0.95 ± 0.28	0.09 ± 0.02	0.70 ± 1

Within rows, means ± S.D., n = 4

protected and unprotected forests were significant ($P< 0.01$) across the three study zones.

Soil organic carbon (SOC) contents were significantly ($P< 0.01$) higher in the protected sites than the unprotected across the three study zones. SOC values generally ranked optimum across the protected sites in contrast to the unprotected sites where values were all ranked low (Moges et al., 2013). The magnitude of the variation in the SOC contents between the protected and unprotected forests showed the same pattern as that of organic matter, that is, SOC content was twice higher in WP than WU and three times greater in SP and MP than SU and MU respectively.

Total nitrogen contents (Table 3) were significantly higher ($P< 0.01$) in all the protected sites than the adjacent unprotected forest sites. Moreover, on the basis of soil nitrogen ratings suggested by Tekalign (1991), available nitrogen values were ranked medium in all the protected sites as opposed to the generally low values recorded across the unprotected sites. Except for Wungu site which recorded moderate numerical variation in N content between the two forest types, the N content was twice and threefold higher in the protected forest than the unprotected in Serigu and Mognori sites respectively.

The available P contents (Table 3) of the soil under protected forests were markedly and significantly ($P< 0.01$) higher in the protected sites than the unprotected across the three study zones. On the basis of soil P concentration ratings suggested by Hazelton and Murphy (2007), P values were optimal (10 - 17 mg/kg) in WP and MP and high (17 - 25 mg/kg) in SP. However, P values across all the unprotected forest sites varied from low (5 - 10 mg/kg) to very low (< 5 mg/kg).

Cation exchange capacity (CEC) and exchangeable bases

Cation exchange capacity was higher in the protected sites than the unprotected (Table 4). However the level of the differences in CEC values between the two forest types varied across the three study zones. On the basis of CEC rating suggested by Hazelton and Murphy (2007), CEC values ranged from low (6 - 12 cmol (+) Kg^{-1} in WP), to moderate (12 - 25 cmol (+) Kg^{-1} in SP and MP) across the protected sites. Across the unprotected study sites CEC values ranked very low in WU and SU (CEC < 6 cmol (+) Kg^{-1}) and moderate in MU (12 - 25 cmol (+) Kg^{-1}) (Table 4). Significant ($P< 0.01$) differences in CEC values were recorded in Wungu and Serigu sites as opposed to Mognori site where no statistically significant ($P> 0.05$) variation was observed between the protected and unprotected forests.

The exchangeable bases (Ca, Mg, K and Na) greatly varied with study zone. Across the three study locations, the exchangeable bases values were higher in the protected sites than the unprotected. According to exchangeable Ca concentration rating (Hazelton and

Table 4. Cation exchange capacity and soil exchangeable Ca, Mg, K, and Na as affected by forest management type.

Forest type	Exchangeable Bases (cmol (+) Kg^{-1} soil)				
	Ca	Mg	K	Na	CEC
WP	1.5 ± 0.4	3.9 ± 1.07	0.24 ± 0.11	0.15 ± 0.02	6.11 ± 1.35
WU	0.5 ± 0.11	1.2 ± 0.29	0.16 ± 0.01	0.13 ± 0.01	2.4 ± 0.5
SP	3.9 ± 0.95	10.43 ± 2.35	0.47 ± 0.08	0.22 ± 0.042	14.91 ± 3.5
SU	1.2 ± 0.28	3.20 ± 0.75	0.17 ± 0.01	0.10 ± 0.01	4.75 ± 1.03
MP	6.2 ± 1.31	15 ± 3.5	0.36 ± 0.09	0.21 ± 0.02	21.69 ± 5
MU	5.2 ± 0.82	10.22 ± 5.18	0.30 ± 0.11	0.20 ± 0.1	16.01 ± 5.06

Within rows, means ± S.D., n = 4.

Murphy, 2007), Ca values were very low (0 - 2 cmol (+) Kg^{-1}) in WP, low in SP (2 - 5 cmol (+) Kg^{-1}) and moderate in MP (5 - 10 cmol (+) Kg^{-1}). Values in the unprotected forests were very low in WU (0.5 cmol (+) Kg^{-1}) and SU (1.2 cmol (+) Kg^{-1}) and moderate in MU (5.2 cmol (+) Kg^{-1}). The Mg contents were high in WP (3.95.2 cmol (+) Kg^{-1}) and very high in SP (10.43 me/100 g) and MP (15 5.2 cmol (+) Kg^{-1}). Across the unprotected forests Mg concentrations exhibited the following ratings: Moderate in WU (1.2 cmol (+) Kg^{-1}), high in SU (3.2 cmol (+) Kg^{-1}), and very high in MU (10.22 cmol (+) Kg^{-1}). The K values were low (0 - 0.2 cmol (+) Kg^{-1}) in WP and moderate (0.3 - 0.7 cmol (+) Kg^{-1}) in SP and MP. K contents across all the unprotected forest sites ranged from very low (0 - 0.2 cmol (+) Kg^{-1}) in WU and STU to moderate in MU (0.3 - 0.7 cmol (+) Kg^{-1}). The Na concentrations were ranked low (0.1 - 0.3 cmol (+) Kg^{-1}) in both the protected and unprotected sites across the three study zones. The variation in exchangeable bases (Ca, Mg, K and Na) between the two forest types was significant (P< 0.01), except for K, and Ca bases in Mognori study site were no significant (P> 0.05) differences were recorded.

Available soil micronutrients (Fe, Mn, Zn, and Cu)

Iron status: Data in Table 5 show that Fe contents were very high (> 10 mg/kg) for both forest types across the three study zones. Except for Mognori site, Fe contents were significantly lower in the protected forests than the unprotected. Significant (P< 0.01 and P< 0.05) variations in Fe contents between the protected and unprotected forests were recorded across the three study zones.

Manganese status: Table 5 shows that Mn values were significantly higher (P< 0.01) in the protected forest sites than unprotected. Mn values ranged from very high (> 6 mg/kg) to high (3.5 - 6 mg/kg) in the protected and unprotected forest sites respectively (Motsara and Roy, 2008).

Copper status: Results in Table 5 further shows that except for Wungu site, Cu concentrations in the soils were higher in the protected sites than the unprotected. The data show that Cu values were very high (> 3 mg/kg) in MP, and high (0.8 - 3 mg/kg) in SP and WP. Values recorded in the unprotected forest sites ranked very high in MU and WU and high in SU (Motsara and Roy, 2008). Significant (P< 0.01) difference was recorded in Cu status between the two forest types across the three study zones.

Zinc status: Zinc contents (Table 5) in the soils were higher in the protected forests than the unprotected. The observed differences in Zn values between the two forest types were significant (P< 0.01 and P< 0.05) in Serigu and Mognori sites as opposed to Wungu where no significant (P> 0.05) variation was recorded between the protected and unprotected forests. Zinc values ranked very high (> 5 mg/kg), and generally high (3 – 5 mg/kg) in the protected and unprotected sites respectively (Motsara and Roy, 2008).

DISCUSSION

The relatively low clay contents recorded across the three study zones are in consistent with findings reported by previous authors (Senayah et al., 2005). This is could be due to the loss of dispersable clay through erosion or leaching to the subsoil as soils in the savanna ecological zone of Ghana are very susceptible to erosion as well as compaction (Callo-Concha et al., 2012). The finding in this study substantiate this fact as the bulk density values were high (1.35< b ≤ 1.55 g/cm^3) across the unprotected forest sites, indicating that the soils under these forests were compacted. This situation could be due to the adverse effects of anthropogenic activities across these forests, since it is established that deforestation leaves the land more susceptible to soil degradation including higher soil bulk density, lower hydraulic conductivity, and higher soil erosion (Spaans, 1989). The study finding therefore points to the need of regulating human activities across the off-reserve forests as well as stepping up

Table 5. Mean values of available micronutrients (Fe, Mn, Zn and Cu) as affected by forest management type.

Forest type	Micronutrients (mg/kg)			
	Fe	Mn	Zn	Cu
WP	62 ± 45.86	18 ± 9.02	7 ± 4.40	2 ± 0.7
WU	98 ± 29.60	4 ± 2.54	5 ± 3.56	4 ± 0.54
SP	26 ± 15.26	16 ± 7.18	9 ± 2.6	3.33 ± 1.41
SU	67 ± 9.60	5 ± 0.66	4.5 ± 2.30	1.43 ± 0.92
MP	67 ± 25.80	22 ± 3.06	5.8 ± 0.81	10 ± 0.31
MU	20 ± 7.74	5 ± 1.05	2.6 ± 1.33	11 ± 0.43

Within rows, means ± S.D., n = 4.

protection of existing reserves in the area so as to avoid further deterioration of the physical properties of the soils under these forests.

The low soil pH values recorded in the unprotected forest sites could be attributed to an advanced stage of removal of basic cations from the surface of the soils under these forests as a result of the effect of anthropogenic activities which led to the loss of nutrients mainly through, grazing, bushfires, and logging. The low values of exchangeable bases (Ca, Mg, K and Na) recorded in the unprotected sites as shown in Table 4 are in line with the above inference. Data contained in Table 4 show that protected sites exhibited higher exchangeable base contents probably as a result of better or sufficient nutrient cycling as these protected forest sites recorded significantly ($P< 0.01$) higher organic matter/organic carbon contents (Table 3) than the unprotected. Several studies have substantiated these facts (Teshome et al., 2013).

The low CEC (Table 4) recorded in unprotected forest sites was consistent with the low organic matter/organic carbon contents (Table 4) of the soils under these forests. Indeed, the correlation analysis (Table 6) showed that there was a positive correlation between CEC and organic matter/organic carbon across the three study zones. The low organic matter/organic carbon contents in the unprotected forest sites was probably due to insufficient inputs of organic matter in the soils of these forests as a result of constant removal of organic matter through, grazing, logging and bushfires.

The data on the soil chemistry of the six study sites further showed that total nitrogen (N) contents were generally low in the unprotected sites compared to those recorded in the protected forests. This finding was in line with previous studies which indicated that human activities such as overexploitation, overgrazing, and inappropriate clearing techniques have alterable effects on nitrogen cycle in ecological systems including savannas (Emma et al., 2012). A positive correlation (Table 6) was found between organic matter/organic carbon and available nitrogen across the three study zones suggesting that the generally low nitrogen values recorded in the unprotected sites were due to deforestation. The observed correlation between organic matter/organic carbon and available nitrogen was in line with the fact that most of the soil nitrogen is found in organic form (Singh and Mishra, 2012; Rangel, 2008).

The high and moderate phosphorous (P) contents of the soils in the protected forest sites vis - à-vis the low and very low values recorded in the unprotected forest sites could be attributed to the persistent removal of plant biomass and erosion as a result of the environmentally-degrading human pressures put on these unprotected forests. A positive correlation (Table 6) was found between organic carbon and available phosphorous across the protected areas. This indicates that high contents of organic matter increase the availability of phosphorous in soils. Indeed, Tisdale et al. (1997) buttressed this correlation by pointing out that, about 50% of phosphorous is found in organic form and that decomposition of organic matter produces humus which forms complex with aluminium (Al) and iron (Fe) and protects the P fixation. The low N and P contents recorded in the unprotected forest sites could result in continued decreases in the productivity of these forests over time should the ongoing anthropogenic activities remain unchecked. This foreseeable implication is supported by the fact that nitrogen is the major factor that controls the dynamics, biodiversity, and functioning of many ecosystems (Vitousek et al., 1981) and plays a central role in limiting primary production in terrestrial ecosystems (Bremen and De Wit, 1983). Besides, it is further established that deficiencies of other elements in the natural vegetation are usually only obvious once nitrogen and phosphorus constraints have been alleviated.

The available micronutrients (Fe, Mn, Zn and Cu) contents were generally higher in the protected forest sites than the unprotected. Earlier works (Jiang et al, 2009; Kumar and Babel, 2011) on the influence of land use systems on available micronutrients have corroborated this finding. Positive correlations were found between Mn, Zn, Cu and the organic carbon/organic carbon content across the protected sites indicating that the differences in micronutrient values between the protected and unprotected study sites might be due to

Table 6. Correlation matrix between selected characteristics of soils under protected and unprotected forest sites at each study zone.

Soil characteristics		pH	OM	OC	CEC	TN	P	Clay	Fe	Mn	Cu	Zn
pH	WP	1.0										
	WU	1.0										
	SP	1.0										
	SU	1.0										
	MP	1.0										
	MU	1.0										
OM	WP	0.560	1.0									
	WU	0.853	1.0									
	SP	-0.458	1.0									
	SU	-0.233	1.0									
	MP	-0.972*	1.0									
	MU	-0.804	1.0									
OC	WP	0.560	0.999**	1.0								
	WU	0.853	1.000**	1.0								
	SP	-0.456	1.000**	1.0								
	SU	0.231	0.953*	1.0								
	MP	-0.972*	1.000**	1.0								
	MU	-0.803	1.000**	1.0								
CEC	WP	0.856	0.906	0.906	1.0							
	WU	0.516	0.275	0.275	1.0							
	SP	0.499	0.468	0.544	1.0							
	SU	0.487	0.864	0.928	1.0							
	MP	-0.977*	0.997**	0.997**	1.0							
	MU	-0.794	0.278	0.277	1.0							
TN	WP	0.965	1.000**	1.000**	0.	1.0						
	WU	0.853	1.000**	1.000**	0.275	1.0						
	SP	-0.531	1.000**	0.995**	0.544	1.0						
	SU	-0.001	0.952	0.953	0.864	1.0						
	MP	-0.9541	0.990**	0.990**	0.996	1.0						
	MU	0.307	0.991**	0.320	0.280	1.0						
P	WP	0.490	0.938	0.920	0.833	0.342	1.0					
	WU	-0.721	-0.964*	-0.964*	-0.100	0.964*	1.0					
	SP	0.6825	0.332	0.333	0.968	0.2452	1.0					
	SU	-0.919	-0.537	-0.538	-0.779	-0.358	1.0					

Table 6. Contd.

	MP	-0.9541	0.044	0.043	0.097	0.1775	1.0					
	MU	-0.9189	-0.537	-0.538	-0.779	-0.358	1.0					
Clay	WP	0.207	-0.690	-0.694	-0.325	0.879	0.645	1.0				
	WU	0.059	-0.003	-0.003	0.853	-0.003	-0.750	1.0				
	SP	-0.620	0.919	0.922	0.313	0.954	0.067	1.0				
	SU	0.643	0.990	0.990*	0.954*	0.968*	-0.730	1.0				
	MP	-0.534	0.712	0.711	0.701	0.759	0.498	1.0				
	MU	-0.518	0.925	0.926	-0.108	0.655	-0.307	1.0				
Fe	WP	-0.839	-0.530	-0.502	-0.756	0.632	0.654	-0.156	1.0			
	WU	0.798	-0.856	-0.856	-0.656	0.537	-0.845	0.795	1.0			
	SP	-0.033	-0.901	-0.901	-0.847	0.145	0.707	0.708	1.0			
	SU	0.687	-0.831	-0.830	-0.857	0.627	-0.814	0.990	1.0			
	MP	-0.055	-0.013	-0.013	-1.000	0.133	0.838	0.114	1.0			
	MU	-0.500	-0.188	-0.197	0.604	-0.482	-0.599	-0.040	1.0			
Mn	WP	-0.490	0.938	0.920	0.833	-0.770	0.301	-0.031	0.420	1.0		
	WU	0.197	0.052	0.052	0.946	-0.679	0.675	-0.729	-0.965	1.0		
	SP	-0.933	0.125	0.124	0.759	-0.894	-0.894	0.374	-0.317	1.0		
	SU	0.330	0.848	0.847	0.698	0.678	-0.460	0.948	0.890	1.0		
	MP	0.188	0.121	0.121	0.062	0.014	0.982*	0.329	0.875	1.0		
	MU	0.261	0.257	0.246	-0.172	0.019	0.197	-0.194	0.657	1.0		
Cu	WP	0.880	0.220	0.202	0.583	0.831	-0.284	0.537	-0.899	-0.523	1.0	
	WU	-0.389	-0.138	-0.138	-0.413	0.707	0.362	0.011	0.194	-0.444	1.0	
	SP	-0.671	0.935	0.933	0.275	0.938	0.074	0.848	0.257	0.359	1.0	
	SU	0.808	-0.756	-0.755	0.867	0.553	-0.924	0.933	0.974*	0.765	1.0	
	MP	0.469	0.252	0.254	0.303	-0.243	0.159	0.400	-0.380	0.114	1.0	
	MU	-0.820	-0.788	-0.794	0.513	-0.038	-0.768	0.615	0.750	0.279	1.0	
Zn	WP	0.766	0.382	0.382	0.607	-0.943	-0.081	0.189	-0.292	-0.975*	0.488	1.0
	WU	0.242	-0.276	-0.276	-0.976*	-0.747	-0.259	-0.98	-0.299	0.538	-0.994**	1.0
	SP	-0.308	0.983	0.984	0.668	0.970*	0.469	-0.897	0.053	-0.024	0.855	1.0
	SU	0.456	-0.410	-0.410	-0.046	-0.390	-0.393	-0.349	-0.215	-0.636	0.011	1.0
	MP	0.160	0.070	0.071	-0.152	-0.175	-0.702	-0.003	-0.975*	-0.746	0.576	1.0
	MU	0.893	-0.451	-0.450	-0.983	0.702	0.971*	-0.078	-0.597	0.210	-0.628	1.0

***** Significant at $P < 0.05$, ****** and $P < 0.01$. OM = Organic matter; OC = Organic carbon; CEC= Cation exchange capacity; TN = Total nitrogen.

high inputs of organic carbon in the soils of the protected forest sites where the absence of human disturbances led to high levels of above-ground and below-ground biomass productivity and sustained inputs of organic matter in the soils (Nang and Dioggban, 2015). Kumar and Babel (2011) stated that availability of micronutrients enhanced significantly with increase in organic matter because: (i) Organic matter is helpful in improving soil structure and aeration; (ii) Organic matter protects the oxidation and precipitation of micronutrients into unavailable forms and (iii) Supply soluble chelating agents which increase the solubility of micronutrient contents. Hence, the available Mn, Zn, and Cu were found to increase with increase in CEC (Table 6) of soils under protected due to more availability of exchange sites on soil colloids of which humus was probably an important component as the soils under investigation had relatively low clay contents.

The Cu, Fe, Mn, and Zn contents values were above the critical limits for plant production across the six study sites indicating that deficiency in these micronutrients was very unlikely for any vegetation type growing on these soils. However the high contents of Fe in the soils of the unprotected forests could lead to the formation of complexes leading to hard pan formation; restricting rooting depth and causing infiltration and drainage problems in the soil (Mustapha et al., 2011). Besides, in view of the fact that Cu, Fe, Mn, and Zn contents were lower in the unprotected sites than the protected it could be inferred that if human activities continue unabated the concentrations of Cu, Fe, Mn, and Zn of the soils under these forests could decrease further reach levels that would be incompatible with adequate plant productivity.

Results from the present study indicate that the effect of anthropogenic on the forest-savanna of northern Ghana led to degradation of the soil physical properties and decrease in the macronutrients (N, P, K) and micronutrients (Cu, Mn, Zn) levels. Hence, differences in forest management systems (protected forests versus anthropogenic activities prone forests) have significant influence on the soil quality and health and its sustainable productivity. It could therefore be concluded that if the ongoing human pressures on forest resource, including the reserves, remain unchecked, the following undesirable consequences could arise in the long run:

1. Gradual deterioration of the physical and chemical properties of the forest soils under investigation and subsequent decline in the nutrients supplying capacity of these soils.
2. Gradual decrease in plant biomass productivity of these forests and decrease in forage availability and livestock production in the region as a result.
3. More encroachments on existing reserves and more deforestation in the region
4. Threat to forest resource conservation in the region and communities' livelihoods.

The study therefore indicates the need for employing best forest management practices that will ensure effective monitoring and regulation of human activities in the off-reserve forest areas and prevent encroachments on the existing reserves. The effective enforcement of these management prescriptions along with vigorous reforestation programmes would be the way forward towards mitigating the ongoing deterioration of the plant-soil system, sustaining forest productivity and protecting people’s livelihoods. For in a region where inhabitants depend heavily upon forest resources for their livelihoods, the degradation of the forest-savanna of northern Ghana is a serious threat to the sustainability of their subsistence lifestyle (O’Higgin, 2007).

Conflict of Interests

The author has not declared any conflict of interest.

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