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Forest composition and productivity changes as affected by human activities in the natural forest- savanna zone in Northern Ghana

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Assessing the impact of anthropogenic activities on forest ecosystems dynamics is valuable in managing and maintaining the long-term productivity of forests and ensuring forest ecosystem sustainability and ecological balance. In view of this, the objective of this study was to evaluate the induced effects of anthropogenic activities on the forest-savanna zones in Northern Ghana. The study assessed the impacts on the woody plant species composition and the above-ground and below-ground herbaceous biomass productivity in three forest areas. Three study zones (Wungu, Serigu and Mognori) consisting of two neighbouring forest types, namely the protected and anthropogenic activities prone types were used for the comparative study. 30 × 30 m and 1 × 1 m random plots and subplots were used to determine the vegetation composition and productivity across the three study areas. A total of 96 random samples of above-ground live biomass, and the same number of litter and root biomass samples were collected in both forest types of each study zone to make composite samples for the comparative analysis. Differences in the woody plant composition were observed between the two types of forest across the three study zones. The results show that total above-ground biomass (live plus litter biomass) and total plant biomass (total above-ground plus root biomass) productivity were generally significantly (P< 0.05) lower in all the unprotected than the adjacent protected areas. From the present study, it could be concluded that forest composition and productivity can be protected and sustained by effectively monitoring and regulating anthropogenic activities across the natural savanna ecological zone in Northern Ghana.

Key words: Forest ecosystems, savanna ecological zone, anthropogenic activities, above-ground and below-ground biomass productivity.

INTRODUCTION

Tropical forests are globally important because of both their ecological and economic significance. They produce approximately 75% of the world's wood products and likely contain over half of the planet's biodiversity, despite occupying only 7% of the earth's surface (Thomas and Baltzer, 2002). In addition, much of the world's population

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lives in these regions. 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 therefore the major structuring forces in forest systems including savannas (Belsky and Blumenthal, 1997; ISRIC, 2007).

The magnitude of the impacts of these activities on the savanna forest ecosystem dynamics can be assessed using the vegetation composition and production variability. This approach provides an avenue for adequate predictions of the possible forest ecosystem structural and functional changes over time (Sala and Austin, 1988; Vogt and Persson, 1991). Assessing the induced effects of anthropogenic activities on forest composition and productivity dynamics is therefore essential for addressing the issue of forest ecosystem sustainable management and productivity.

The area of Northern Ghana is one example of savanna ecosystems that is experiencing forest degradation as a result of human activities (O'Higgin, 2007). In Ghana, as in many areas in Africa, the savanna woodland plays important roles in servicing the ecological environment and socio-economics of the region and supporting diverse species of plants and animals (Nsiah-Gyabaah, 1996). However, the persistent exposure of this forest ecosystem to human activities, such as bush burning, overgrazing and logging, constitutes a serious threat to its sustainability and communities' livelihoods (Campbell et al., 2000; FAO, 1998).

The importance of grazing is particularly significant in this region. Therefore the need for fresh green grass leads to the tendency of herders to burn off dry and undesirable vegetation (grasses) and to promote the growth of pasture. However, bushfires causing volatilization of nutrients can reach extremely high temperatures, especially at the end of the dry season when vegetation is very dry. The effects can be damaging to soil structure and plant stability. Fires which burn large tree trunks or destroy the soil organic matter at confined spots often reach temperatures in excess of the threshold value resulting in serious damage to flora, and fauna (Nsiah-Gyabaah, 1996).

The damaging effects caused by persistent bushfires and grazing on plants coupled with over exploitation of plants by people in the form of fuel wood and charcoal, timber and medicinal products as revenue resources adversely affect plant biodiversity conservation in the region (FAO, 1998). The anthropogenic pressures exerted on forest-savanna woody plant components in the form fuel wood collection and charcoal production are so huge as biomass energy is the primary energy source in a majority of rural sub-Saharan areas (Murphy, 2001; FAO, 2007). This situation explains why rural communities in the savanna ecological zone of northern Ghana depend nearly entirely on firewood and charcoal as energy sources for cooking and heating (FAO, 1998; NSBC, 2002). Historically, fuel wood harvesting occurred on individual farmlands and was for household subsistence use only. However, fuel wood exploitation in forest reserves and protected areas has increased considerably over the last decades. Hence, most reserves have thus been depleted of wood resources (NSBC, 2002). If the present trend continues unchecked, most parts of Northern Ghana will easily become desert (FAO, 1998). In a region where inhabitants depend upon natural resources for their livelihoods, the degradation or disruption of the savanna forests has a number of detrimental impacts upon the environment and communities' livelihoods (Campbell et al., 2000). The preservation and conservation of the northern forest-savanna zones is therefore of paramount importance not just for the sake of production of commodities, but more so for maintaining its ecological balance and environmental reasons. This implies that rehabilitation and sustainable conservation are a matter of priorities and should be followed by an in-depth assessment of the state of health of this ecosystem (Afikorah-Danquah, 1997; Wardell et al., 2003). It is therefore important for scientific researchers, the forestry advisory service and local inhabitants to understand the current degradation conditions of the northern forest-savanna zones in order to better analyse them, and explore realistic options for their sustainable management (O'Higgins, 2007).

Despite the persistent pressure of human activities on the forest-savanna zones of northern Ghana, few studies have so far focused on the extent and nature of these human pressures and associated feedbacks on the structural and functional changes of these forest zones (Nsiah-Gyaaba, 1996; O'Higgins, 2007). Nsiah-Gyaaba's research gave a general overview of the causes and environmental impacts of bushfires across the forest-savanna of northern Ghana without carrying out an in-depth assessment of the magnitude of bushfires on the vegetation composition and productivity and the soil physicochemical properties changes. O'Higgins carried out an assessment of human-driven land degradation within the northern savanna woodland by integrating ecological indicators with perceptions of local communities. However, her study was limited in scope as it was conducted in a single study area and characterized by a dearth of comparison of the extent of soil degradation of unprotected forest areas versus conservation performance of protected forest sites. Besides, she did not integrate in her assessment the biomass productivity variability. Hence, the present research seeks to bridge these gaps. The research assesses the induced effects of anthropogenic activities on forest- savanna zones composition and productivity changes using a comparative study between protected and unprotected forest sites.

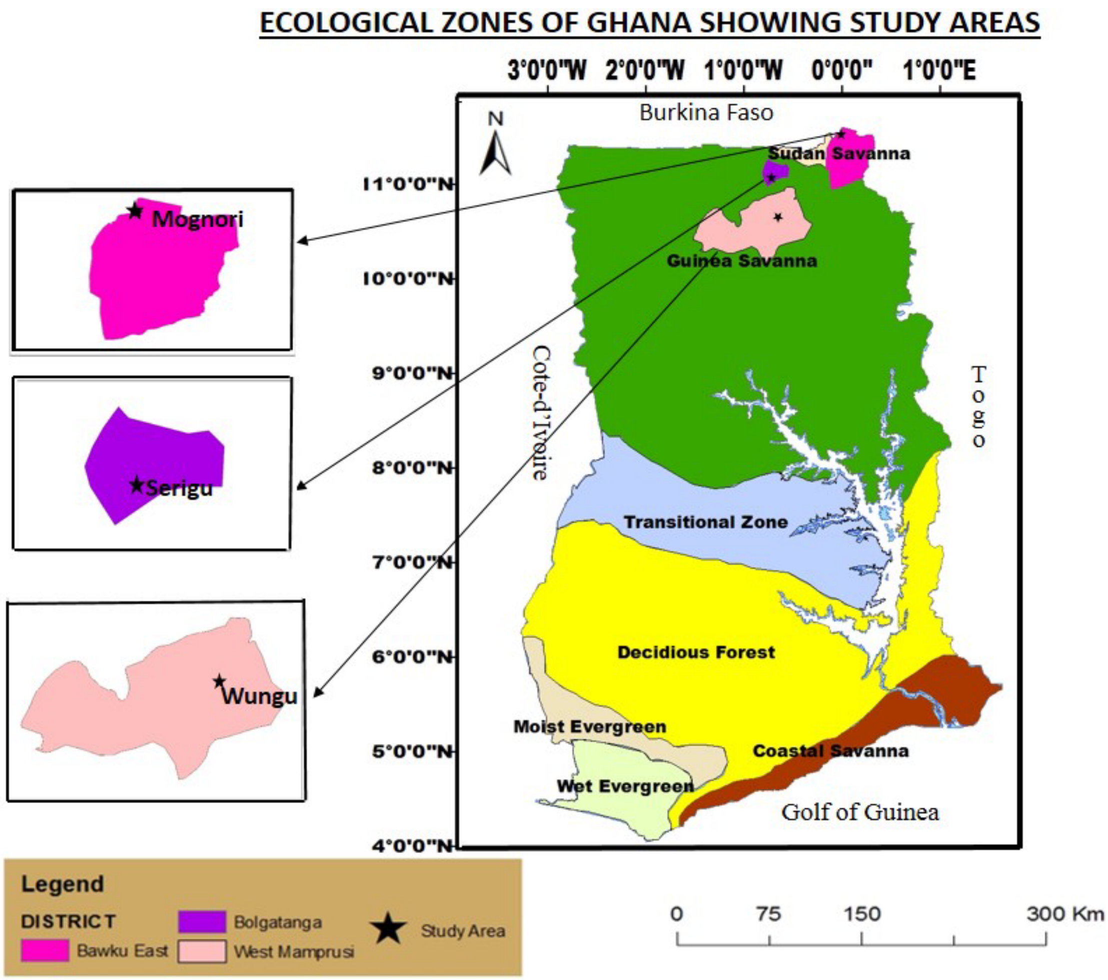

Figure 1. Ecological zones map of Ghana showing the location of study areas.

For the sake of the genera-lizability of the findings to the entire savanna ecological of Northern Ghana, the study was carried out in three study zones which exhibit the main characteristics of the savanna ecological zone, that is, the subhumid savanna and semi-arid savanna.

The study compares the woody plant species composition and the above-ground and below-ground herbaceous biomass productivity in three unprotected and three neighbouring well protected forest sites. The underlying objective of the research was to generate data that will contribute to a better understanding of the human driven impacts on the dynamics and sustainability of the natural forest-savanna zones of northern Ghana.

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) (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 characterised 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 - 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), with torrential rains creating serious drainage problems.

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 to 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 (FAO, 1998). The total conserved of the northern Ghana savanna area is about 15 million hectares. The reserved forest which were 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 (FAO, 1998).

Site selection and plot demarcation

Three study zones (Wungu, Serigu and Mognori) were used for the comparative study. Each zone consisted 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 well fenced (for easy location and protection) and monitored random plots were set in both the protected and neighbouring unprotected forest sites of each study zone from late March (late dry season) to late August 2013 (late peak rainy season) and used for the generation of data for the comparative study. The random demarcation of 30 m × 30 m study plots and 1 m × 1 m subplots was effected using the data management/random selection tools of the ArcGIS software which was used to create a digitized grid map of the study areas within which were selected random points representing the location of study plots and subplots in the field. The random points coordinates as indicated on the grid map were recorded in the eTRex GPS and used in the field to locate and demarcate the 30 × 30 m and 1 × 1 m random plots and subplots.

Tree species composition inventory

For the inventory of woody plants each 30 m × 30 m random plot was subdivided into three equal transect strips of 30 m × 10 m. The counting and identification of tree species composition was carried out within the transect strips using the required standard inventory procedures (Rob et al., 1997; Kuers, 2013). The rationale behind dividing the plots into transect bands was to ensure an easy, painstaking, and accurate counting and identification of all tree individuals within the demarcated plots.

In each transect band all rooted live woody plants were counted and identified to determine tree species, species density and frequency, and total forest density. The DBH (diameter at breast height) of all tree individuals greater than or equal to 2 m tall were recorded within the transect bands from 1.4 m above the ground using a DBH measuring tape and established procedures thereof (Burns and Honkala, 1990; Kuers, 2013). The diameter tape does not measure the diameter directly, but instead measures the circumference of the tree. The circumference (C) was converted to diameter by solving for DBH in the following equation:

$C = \pi \times DBH$ hence, $DBH = C/\pi$

Where, C = circumference of tree, π= 3.14, DBH = diameter of tree at breast height.

Method of calculating species importance value (IV): The quantitative data obtained from the inventory of tree individuals were used for the calculation of the relative degree of importance of tree species within the plant community, also known as Importance Value (IV) (Kuers, 2013). Importance values rank tree species within a site based upon three criteria:

a) How commonly a species occurs across the entire forest;
b) The total number of individuals of the species;
c) The total amount of forest area occupied by the species.

Therefore, a tree species importance value is the sum of the relative frequency, density, and dominance of the species which were calculated from the data obtained from the forest inventory across the three study zones.

To make it easier to compare communities that may differ in size, or that were sampled at different intensities, importance values are calculated using relative rather than absolute values. Hence, tree species Importance Value (IV) **=** Relative frequency **+** relative density **+** relative dominance**.** The higher the importance value, the more dominant a species is in that particular community. The relative frequency, density, and dominance were calculated using the following formulas (Kuers, 2013):

$$\text{Frequency} = \frac{\text{Number of plots in which the species is found}}{\text{Total number of plots sampled}}$$

$$\text{Relative frequency} = \frac{\text{Frequency of individual species}}{\text{Sum of frequencies of all species}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of a given species}}{\text{Total area of measured plots in acre or hectare}}$$

$$\text{Relative density} = \frac{\text{Density of individual species}}{\text{Sum of densities of all species}} \times 100$$

$$\text{Dominance (Basal area)} = \frac{\text{Sum of basal area of each species from all inventoried plots}}{\text{Total area of measured plots in acre or hectare}}$$

$$\text{Relative dominance} = \frac{\text{Sum of basal area of individual species}}{\text{Sum of basal areas of all species}} \times 100$$

The basal area is the cross-sectional area of a tree at breast height. The cross-sections of trees are, for simplicity, considered circles. Hence, the basal area was calculated using one of the following equations (Kuers, 2013):

Basal area (BA) = $\pi r^2 = \pi \times DBH^2/4 = DBH^2 \times \pi/4$, hence,
Basal area (BA) = stem DBH (cm) x DBH (cm) x 0.00007854 = BA in m^2 per tree or
(BA) = stem DBH (in) x DBH (in) x 0.005454 = BA in m^2 per tree
Where, π= 3.14, DBH = diameter of tree at breast height determined from the circumference.
The maximum importance value for any one species is 300 (that is, 100 + 100 + 100).

Method of calculating forest density: Forest density values for the six study sites were estimated as follows:

Forest density: Total number of tree individuals tallied for all species divided by the total area of the measured plots (in acres or hectares) to give the number of trees per acre or hectare for the forest community (Kuers, 2013).

$$\text{Forest density} = \frac{\text{Total number of tree individuals of all species}}{\text{Total area of measured plots in acre or hectare}}$$

Total area of measured plots = area of a single plot in hectare x total number of measured plots, i.e. 30 m × 30 m × 4 plots = 900 m^2 × 4 = $\frac{3600}{10000}$ ha = 0.36 ha. Hence,

$$\text{Forest density} = \frac{\text{Total number of tree individuals of all species}}{0.36 \text{ ha}}$$

Biomass production measurement

Above-ground and Below-ground herbaceous plant biomass were harvested from within four 1 m × 1 m random subplots of each 30 × 30 m plot across the three study zones. The biomass sampling was carried out in late August at both sites of each study zone, at the time when most grasses had reached their maximum growth (peak biomass) after which senescence starts. In predominantly herbaceous ecosystems such as grass lands, the aboveground net primary production (ANPP) may be estimated by measuring the peak of herbaceous biomass, assuming that aboveground plant tissues would dieback completely each growing season and that above-ground biomass would increase up to a point after which senescence occurs (Sala and Austin, 1988).The plants on all our study sites are predominantly herbaceous and meet the above assumptions. The ANPP on each study plot was therefore determined by measuring the peak herbaceous biomass.

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. Our timing of harvesting coincided with the approximate time of peak above-ground biomass in the study area (late August). 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. Harvests consisted of a total of 96 random samples of above-ground live biomass, and the same number of litter and root biomass samples collected in both forest types of each study zone and used to make composite samples.

Plant material 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.

Above-ground and Below-ground herbaceous plant biomass were determined as follows (Zhiyong et al., 2006)**:**

a) Above-ground live biomass (AGLB):

__Step 1__**:** Determination of dry weight for 100 g of live biomass clip harvested within a 1 × 1 m or $1m^2$ subplot =**A** (g/m^2).

__Step 2__**:** Determination of total dry weight **C** (g/m^2) for total fresh biomass **B** (g/m^2) clip harvested within a 1m x 1m subplot.

$$C_{AGLB}\ (g/m^2) = \frac{\text{Total fresh biomass weight B } (g/m^2) \times A(g/m^2)}{100}$$

within a 1 m × 1 m subplot.

b) Litter: Same method as for Above-ground live biomass.

c) Root Biomass (RB) was determined as follows:

__Step1__: Determination of dry weight for 100g of fresh root biomass in a root core of 20cm diameter and a 20 cm depth within $1m^2$ = **A** (g)

__Step2__: Determination of total dry weight **C** (g) for total fresh root biomass **B** (g) in a root core of 20 cm diameter and a 20 cm depth within a 1m x 1m subplot.

$$C_{RB}\ (g) = \frac{\text{Total root biomass weight B (g) x A(g)}}{100}$$

C_{RB}(g) was the value of dry root biomass weight in a root core of 20 cm diameter and 20 cm depth equivalent to an area of πr^2 that is,

3.14 x $(\frac{20}{2})^2 Cm^2$ or 314 x $10^{-4} m^2$

Where r = radius of 20 cm diameter, π = 3.14

__Step3__: For an area of a 1m x 1m subplot or $1m^2$ with the same depth, total dry root biomass D_{RB} (grams per square meter) was

$$D_{RB}\ (g/m^2) = \frac{C_{RB} \times 10^4}{314\ m^2}$$

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 0.01significance levels.

RESULTS

Changes in plant species composition and forest cover

The study revealed differences in plants species composition between the protected and unprotected sites across the three study zones (Tables 1, 2 and 3). In Wungu protected forest site (West Mamprusi District), major tree species were *Daniellia oliveri, Azederica indica, Afzelia Africana, Anogeissus leiocarpus, and Nauclea latifolia* with 43.93, 38.5, 27.01, 26.21 and 24.29% as respective importance values. In the adjacent unprotected forest site, dominant species were *Pericopsis laxiflora* (40.36%), *Diospyros mespiliformis*

Table 1. Tree species composition and importance value (I. V.) at Wungu study site.

Wungu protected forest site		Wungu unprotected forest site	
Species	**I. V.**	**Species**	**I. V.**
Acacia sieberiana	3.	*Acacia dudgeon*	5.67
Afzelia Africana	26.99	*Acacia sieberiana*	19.46
Anogeissus leiocarpus	26.21	*Anogeissus leiocarpus*	21.26
Anona senegalensis	2.45	*Azederica indica*	21.26
Azederica indica	38.5	*Calotropis procera*	22.16
Bombax costatum	6.4	*Combretum ghalensis*	3.4
Borassus aethiopum	2.69	*Combretum glutinasum*	6.17
Calotropis procera	2.45	*Crossopteryx febrifuga*	15.49
Ceiba pentadra	8.25	*Diospyros mespiliformis*	6.56
Combretum glutinasum	4.57	*Entada Africana*	2.31
Crossopteryx febrifuga	4.67	*Erythrophellum Africana*	2.16
Daniellia oliveri	43.93	*Ficus lepiri*	2
Dichrostachys glomerata	7.8	*Gardenia aqualla*	2
Diospyros mespiliformis	9.16	*Grewia mollis*	2.16
Entada abyssinica	2.7	*Grewia lacoides*	2
Erythrophellum Africana	2.47	*Lannea acida*	9.13
Haematostaphis barteri	2.47	*Lannea barteri*	2.16
Khaya senegalensis	10.76	*Mitragyna inermis*	7.41
Lannea acida	4.55	*Moringa oleifera*	2.16
Lannea microptera	4.95	*Pericopsis laxiflora*	40.36
Licus lepiri	12.25	*Prosopis Africana*	24.2
Nauclea latifolia	24.29	*Pteroscarpus erinaceus*	2
Paidum guajava	4.97	*Sclerocarya birrea*	2
Parkia biglobosa	8.51	*Securidaca longepeduncula*	3.59
Pericopsis laxiflora	6.97	*Securinega virosa*	2.78
Prosopis Africana	6.4	*Stereospermum kunthianum*	17.36
Securidaca longepeduncula	2.45	*Tamarindus indica*	4.55
Tamarindus indica	2.58	*Terminalia avicennoides*	2.47
Terminalia avicennoides	7.17	*Terminalia macroptera*	18.53
Terminalia macroptera	6.14	*Vitellaria paradoxa*	20.34
Vitellaria paradoxa	10.33	*Vitex dionana*	2

(26.56%), *Prosopis Africana* (24.20%), *Calotropis procera* (22.16), *Anogeissus leiocarpus* (21.26%), and *Vitellaria paradoxa* (20.34%). In Serigu protected forest site (Bolga District), *Combretum ghalensis* (62.25%), *Combretum nigricans* (60.85%), *Diospyros mespiliformis* (32.36%) and *Anogeissus leiocarpus* (27.36%) were the most dominant species. Major species in the neighbouring unprotected site were *Adansonia digitata* (52.4%), *Diospyros mespiliformis* (35.17%), *Lannea acida* (34.35%), *Combretum ghalensis* (31.7%), *and Pilostigma thonningi* (28.7%), and *Combretum nigricans* (26.79%). In Mognori forest reserve (Bawku District), *Brya ebenus* (72.85%), *Tectona grandis* (47.47%), *Cassia alata* (41.93%), and Sp *Albizia* (29.59%) were most dominant species. In the adjacent unprotected forest, major plant species were *Pilostigma thonningi* (66.68%), *Acacia sieberiana* (57.79%), *Tamarindus indica* (47.38%), and *Acacia gregii* (40.01%).

With regard to the forest density, the study showed differences between the protected and unprotected forest sites across the three study zones. In Wungu and Serigu, the woody plant density was twice greater in the protected site than the unprotected. In Mognori, the forest density was sixfold higher in the protected site than the unprotected (Table 4).

Changes in total above- and below-ground biomass

Total above-ground biomass (live plus litter biomass) was significantly lower ($P< 0.05$ and $P< 0.01$) in the unprotected study sites than the protected across the three study zones (Table 6). Differences in above-ground biomass between the protected and the unprotected sites were threefold in Wungu, fourfold in Serigu and twofold in Mognori (Table 5).

Table 2. Tree species composition and importance value (I. V.) at Serigu Tangabesi study site.

Serigu protected forest site		Serigu unprotected forest site	
Species	**I. V.**	**Species**	**I. V.**
Acacia dudgeon	5.11	*Acacia gourmaensis*	3.42
Acacia nilotica	2.2	*Acacia nilotica*	12.27
Acacia sieberiana	2.01	*Adansonia digitata*	52.4
Azardireca indica	2.01	*Annona senegalensis*	4
Adansonia digitata	2.01	*Anogeissus leiocarpus*	17.23
Annona senegalensis	5.01	*Bombax costatum*	10.94
Anogeissus leiocarpus	27.36	*Combretum ghalensis*	31.7
Balanites aegyptiaca	2.01	*Combretum nigricans*	26.79
Bombax costatum	2.63	*Diospyros mespiliformis*	35.17
Calotropis procera	2.38	*Gardenia aqualla*	4.88
Combretum ghalensis	62.25	*Lannea acida*	34.35
Combretum glutinasum	5.11	*Maytenus senegalensis*	11.98
Combretum nigricans	60.85	*Pilostigma thonningi*	28.7
Crossopteryx febrifuga	2.01	*Sterculia setigera*	10.62
Diospyros mespiliformis	32.36	*Stereospermum kunthianum*	3.42
Faidherbia albida	3.08	*Strychnos spinosa*	3.71
Lannea acida	19.19	*Terminalia avicennoides*	7.12
Maytenus senegalensis	9.6	*Vitex dionana*	3.42
Pericopsis laxiflora	2.01	*Ximenia Americana*	6.34
Pilostigma thonningi	16.18		
Pterocarpus erinaceus	6.73		
Sclerocarya birrea	5.11		
Sterculia setigera	21.34		
Stereospermum kunthianum	7.84		
Strychnos spinosa	2.2		
Tamarindus indica	4.75		
Terminalia avicennoides	7.08		
Ximenia Americana	17.43		

Below-ground biomass (0-20 cm) was significantly greater ($P < 0.01$) in Wungu between the two forest types while no significant ($P > 0.05$) difference was observed between the protected and unprotected sites in Serigu and Mognori (Table 6). Below-ground biomass was two times greater in the protected sites than the unprotected in Wungu and Serigu, and fourfold higher in Mognori (Table 5). Total plant biomass (total above-ground plus root biomass) was significantly ($P < 0.01$ and $P < 0.05$) lower in the protected sites than the unprotected in Serigu and Mognori. However, significant ($P = 0.05$) difference was not recorded in total plant biomass between the two forest types in Wungu (Table 6). Total plant biomass was tree times greater in the protected site than the unprotected in Serigu and Mognori, and twice higher in Wungu protected forest site (Table 5).

DISCUSSION

Anthropogenic activities have contributed to accelerated forest degradation in northern Ghana. In a region where inhabitants depend upon natural resources for their livelihoods, degradation of such resources is a serious threat to the sustainability of a subsistence lifestyle (O'Higgins, 2007). The understanding of the associated human-induced impacts on the dynamics of forest areas in the savanna ecological zone of northern Ghana is therefore essential in ensuring their sustainable management and ecological balance. In this study we evaluated the effects of anthropogenic activities on the forest-savanna composition and productivity using three forest-savanna zones in three districts of northern Ghana as a case study.

It has been widely established that human activities such as bushfires, grazing and logging are factors aggravating and accelerating forest-savanna and land degradation processes (Stocking and Murnaghan, 2001). It has been further demonstrated that deforestation has relevance and relates to issues of forest fragmentation, which impact on species numbers, composition and biodiversity (Hill and Curran, 2001). The research findings in this study were in line with the above

Table 3. Tree species composition and importance value (I. V.) at Mognori study site.

Mognori Protected forest site		Mognori Unprotected forest site	
Species	**I. V.**	**Species**	**I. V.**
Acacia dudgeon	8.62	*Acacia gourmaensis*	21.66
Acacia gourmaensis	6.24	*Acacia gregii*	40.01
Acacia nilotica	6.42	*Acacia sieberiana*	57.79
Acacia sieberiana	1.78	*Anogeissus leiocarpus*	8.69
Anogeissus leiocarpus	1.78	*Azederica indica*	20.39
Azederica indica	13.64	*Pilostigma thinning*	66.68
Balanites aegyptiaca	14.56	*Sclerocarya birrea*	19.27
Brya ebenus	72.85	*Strychnos spinosa*	8.69
Burkeya Africana	5.59	*Tamarindus indica*	47.38
Cassia alata	41.93	*Vitellaria paradoxa*	9.44
Chorisia speciosa	5.35		
Ficus lepiri	1.9		
Gardenia aqualia	3.57		
Khaya senegalensis	5.41		
Lannea macrocarpa	8.03		
Parkia biglobosa	5.29		
Sclerocarpa macrocarpa	1.82		
Sclerocarya birrea	5.11		
Sp Albizia	29.59		
Strychnos spinosa	1.84		
Tamarindus indica	5.41		
Tectona grandis	47.47		
Vitellaria paradoxa	5.82		

Table 4. Forest density as affected by forest management type at the six study sites.

Study area	Total number of tree individuals	Total area of inventoried plots (ha)	Density (number of trees per ha)
WP	1354	0.36	3761
WU	644	-	1789
SP	575	-	1597
SU	343	-	953
MP	1683	-	4675
MU	292	-	811

established facts, as the persistent anthropogenic activities have markedly reduced the vegetation cover in the unprotected forests compared to the protected areas. In contrast to the protected areas, the unprotected forest sites recorded significantly low vegetation density values across the three study zones (Table 4). This has an important implication for the forest-savanna management and sustainability because vegetation cover is often used to asses spatial extent and degree of desertification (Soyza et al., 2004). In line with this implication, it appears that the potential of aggravating to forest depletion in northern Ghana as a result of the ongoing human pressures is so huge as rural communities in the savanna ecological zone depend nearly hundred percent on firewood and charcoal for energy sources for cooking and heating (NSBC, 2002; FAO, 2007). This situation could be exacerbated by the inadequate promotion of substitute sources of energy such as the development of commercial plantations and the use of combustible gas. The results of the study further revealed some differences in plant species composition between the two types of forest across the three study zones. These findings substantiate those reported by several authors who established that anthropogenic activities in the savanna woodland can lead to interference of the natural balance between abundance of species that is, selecting

Table 5. Plant biomass (g/m^2) as affected by forest management type at the three study zones.

Ecosystem component	Forest management system	
	Protected forest	Unprotected forest
Above ground	**WP**	**WU**
Live biomass	612 ± 286	195±67
Dead biomass (litter)	247 ± 201	104 ± 92
Total above ground biomass	859 ± 325	299±83
Roots		
0 - 20 cm	1517 ± 339	682 ± 48
Total plant biomass	2376 ± 324	981 ± 83
Above ground	**SP**	**SU**
Live biomass	361 ± 166	167 ± 103
Dead biomass (litter)	423 ± 64	29 ± 15
Total above ground biomass	784 ± 150	196 ± 73
Roots		
0 - 20 cm	609 ±137	345 ± 227
Total plant biomass	1393 ± 150	541 ± 166
Above ground	**MP**	**MU**
Live biomass	76 ± 20	72 ± 20
Dead biomass (litter)	91 ± 39	10 ± 5
Total aboveground biomass	167 ± 37	82 ± 16
Roots		
0 - 20 cm	1006 ± 489	273 ± 43
Total plant biomass	1173 ± 328	355±32

Within rows, means ± S.D. (n = 4).

only desirable species over others (Sillah, 1999; Haberl et al., 1994). The associated implication of this finding is the possible scenario of continued dwindling of plant biodiversity of the area if the situation is unchecked. This could adversely affect the communities as they depend on biodiversity for their livelihood, nutrition and health. Eptsein et al., (2003) exemplified this corollary in their research on biodiversity and health by establishing that human health, biodiversity and poverty reduction represent a nexus of interrelated issues that lie at the centre of human development.

The magnitude of impact that anthropogenic activities have on the savanna forest ecosystem functioning can further be assessed using plant biomass quantification methods (Sala and Austin, 1988; Vogt and Persson, 1991). In this study we demonstrated that differences in savanna forest management practices lead to differences in biomass productivity.

Our results show that total above-ground biomass (live plus litter biomass) and total plant biomass (live + litter + roots biomass) were significantly lower ($P < 0.05$ and $P < 0.01$) in all the unprotected sites than the protected forest sites across the three study zones (Table 5). The persistent removal of above-ground biomass as green fodder coupled with logging, burning were likely accountable to the low forest density and productivity in the unprotected forest sites.

The decrease in above-ground and below-ground biomass productivity could therefore be explained by low inputs of organic matter in the soils under unprotected forests and low nutrients cycling as a result of the continued removal of plant biomass. This situation could drastically reduce the biomass productivity over time, as the sustainable productivity of a soil mainly depends upon its ability to supply essential macro- and micro-nutrients to the growing plants (Malher, 2004). Many studies have indeed substantiated the importance of organic matter to soil nutrients cycling by indicating that, abundance of organic matter in the soil affects and is affected by plant production and its role as a key control of soil fertility has been established (Tiessen et al., 1994).

The plant biomass production decreasing trend as

Table 6. Summary of the analysis of variance (ANOVA) outputs between protected and unprotected sites at each study zone.

Ecosystem component	F– Value	P – value	Outcome	
Live biomass				
Wungu	8.10	0.029	P< 0.05	Significant
Serigu	25.542	0.002	P< 0.05	Significant
Mognori	0.12	0.743	P > 0.05	Not significant
Litter				
Wungu	1.40	0.28	P > 0.05	Not significant
Serigu	174.86	0.000	P< 0.01	Significant
Mognori	18.38	0.005	P< 0.01	Significant
Root biomass				
Wungu	23.800	0.003	P< 0.01	Significant
Serigu	0.92	0.38	P> 0.05	Not significant
Mognori	8.12	0.29	P> 0.05	Not significant
Total above ground biomass				
Wungu	7.9	0.015	P< 0.05	Significant
Serigu	24.12	0.000	P< 0.01	Significant
Mognori	6.98	0.019	P< 0.05	Significant
Total plant biomass				
Wungu	4.3	0.05	P = 0.05	Not significant
Serigu	8.5	0.008	P< 0.01	Significant
Mognori	6.94	0.015	P< 0.05	Significant

observed in the unprotected forest areas under intense and unregulated anthropogenic activities is likely to reduce the forage supply in the region in the long run, this could result in adverse effects on livestock production and drastic reduction in animal proteins supply in the region.

Hence, this study indicates that proper regulation of human activities across the forest-savanna zones of Northern Ghana is an imperative in ensuring their sustainable conservation and productivity and sustaining the inextricable nexus between forest resources use and communities' livelihoods.

Conclusions

Based on the findings of the present study it appears that differences in forest management systems (protected versus anthropogenic activities prone forests) have significant influence on the forest vegetation composition and productivity dynamics and sustainability. This indicates the need for employing appropriate and effective management plans for monitoring and regulating anthropogenic activities across the northern forest- savanna zones so as to ensure their long-term sustainability and ecological balance necessary to sustain people's livelihoods. The results showed some similarities and differences in woody plant species composition between the protected and unprotected forest sites. This indicates the complementarity between forest reserves / sacred groves and the unprotected forest areas in providing the full extent of plant species diversity in the savanna forest zones. The finding further stresses the need to intensify the protection of existing forest reserves and sacred groves, and indeed the importance of establishing new forest reserves. Moreover, failure to intensify the protection of existing reserves and sacred groves could result in encroachment on them and threat to their survivability. This situation could lead to a severe depletion of the vegetation cover and loss of plant diversity, and in a long term perspective on an ecological timescale to changes in the climatic conditions and desertification.

Besides these measures, ex-situ savanna plant diversity conservation in the form of botanical gardens and seeds conservation centers in all the three regions which make up the savanna ecological zone should be seriously explored.

Furthermore, in order to satisfy and sustain the energy demand of the local communities as a result of the restrictive management prescriptions suggested above, substitutes for firewood and charcoal become an imperative. The study therefore suggests the promotion and adequate subsidization of combustible gas by the government coupled with the development and promotion of less environmentally hazardous and sustainable sources of energy such as solar panels or wind turbines.

In addition to these measures, intensive livestock production policy should be vigorously pursued. The requisite technical know–how thereof should be made easily accessible to farmers and the policy should be logistically and financially supported by both the public and private sectors.

Conflict of interests

The authors did not declare any conflict of interest.

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