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Population Density and Diversity of Trees on Farmlands in Three Districts of the Upper East Region of Ghana: Implications for Food Security and Ecosystem Sustainability

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Authors' contributions

This work was carried out in collaboration with all authors. Authors SEA and GKA designed the study, collected all primary data and wrote the protocol for the study. Authors SEA, MMA and MKA performed the data analysis. Authors SEA, MKA and DK wrote the first draft of the manuscript and managed the literature searches. All authors read and approved the manuscript.

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ABSTRACT

Ghanaian farmers have been practicing farming since time immemorial and trees are a normal component of farmlands. However, the choice of particular tree species and their population on the farms is greatly influenced by the farmers' preferences and therefore, the utility value placed on particular tree species. This study was conducted to determine the number of trees per unit area of farmland, the diversity of the tree species, and the factors that influence farmers' decision to leave trees on their farms in three districts of the Upper East region of Ghana. It also seeks to determine

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any relationship between tree density and the yields of commonly cultivated crops in the study area. The area falls within the Guinea and Sudan savanna zones, characterized by a short unimodal rainfall regime (about 5 months) and a rather long dry season. Twelve communities (4 per district) were randomly selected and farmers were interviewed on their reasons for allowing trees on their farmlands as well as the yields of major crops cultivated. Ten farms in each community were also randomly selected and inventories of trees were conducted, where trees were identified, and enumerated. Farm sizes were also measured. Mean tree population densities on farms were 18.5, 18.4 and 25.9 trees per hectare in the Garu-Tempane, Bawku West and Kassena Nankana West districts respectively. A Shannon Weiner diversity index of 1.563, 1.195 and 1.551 were calculated for Garu-Tempane, Bawku West and Kassena Nankana West districts respectively. Forty-two (42) different tree species belonging to 23 families were encountered in Garu-Tempane district, 28 species from 18 families were encountered in the Bawku West district and 37 species belonging to 21 families in the Kassena Nankana West district. *Azadirachta indica, Combretum molle, Diospyros mespiliformis* were the commonest on all farms. Factors that influenced farmers' decision to allow trees on their farms were shade (22%), fuelwood (18%), food (15%), medicine (13%), housing (13%), soil improvement (10%), erosion control (7%), fodder (1%) and others (1%). Crop yields were generally high in the Bawku West district and there was no significant relationship between tree population density and the yields of crops.

Keywords: Population density; species diversity; species richness; agroforestry; tree-crop interaction.

1. INTRODUCTION

Ghanaian farmers have been practicing agroforestry since time immemorial by deliberately leaving some tree species on their farms. The importance of trees to the livelihood of farmers is considered in terms of agricultural production systems, forest products collection and income generation [1-4]. This is based on the understanding that these resources serve to supplement existing food resources and household income, fill in seasonal shortfalls of food and income as well as provide seasonally crucial agricultural inputs [5]. These resources appear to be especially important for the rural poor who largely rely on off-farm employment opportunities to address their household needs. The potential of tree-based cropping systems for increasing crop productivity in arid and nutrient-deficient smallholder farming systems cannot be overemphasized [6]. However, tree-crop interactions can have both positive and negative effects on the structure and functioning of the agro-ecosystem [7]. Trees can compete with crops for light, water and nutrients and decrease crop yield when density and size of trees are high [8-11] as well as allelopathic effects. On the other hand, some tree species are known to have certain characteristics that enable them to provide favourable conditions for improved crop growth and yield. These may include addition of essential nutrients to the soil for crop use, and improvement in soil physical and biological conditions. Trees therefore play a more holistic role in contributing to soil fertility than inorganic fertilizers which only add specific nutrients to the soil [6,12].

Trees provide other functions which altogether enable them to be left on farms to grow among field crops. These functions may include the provision of food, shade, fodder, fuelwood, medicine, building materials, windbreaks and erosion control [13]. The types of tree species planted or allowed to grow on farms will depend on the extent and variety of these functions they perform as well as the farmer's needs or preferences. Farmers therefore have adequate knowledge of the roles played by individual trees left on their farms and for which reason selected trees are allowed to grow on farmlands.

In Ghana, and especially the Upper East Region, land degradation has resulted in serious environmental problems with devastating socio-economic impacts on rural populations whose poverty levels are exacerbated by the steady deterioration of their natural resource base including vegetation [14]. The impact of land degradation is most severely felt in the northern Ghana, where both incidence and depth of poverty are greatest [14], and where only a marginal decrease in poverty rates has been recorded, even though Ghana's overall poverty has reduced considerably [15]. Poverty rates in the three northern regions are two to three times the national average [15]. Human activities such as rampant bushfires, inappropriate cultural practices including "slash and burn" and continuous cropping, have resulted in dwindling

diversity and population of trees species on farmlands and ecosystem, thereby depriving these resource-poor farmers the numerous benefits of trees. These practices have negative repercussions on soils and hence agricultural productivity. The poor soils (Savanna Ochrosols, Luvisols, Leptosols and Fluvisols) in the area have also resulted in low crop yields with consequences on food security and poverty [15].

In an area where poverty levels are such that inorganic fertilizers are hardly affordable, trees can become a strong candidate for sustainable agricultural production. Tree based strategies designed to adapt to drought and prevent land degradation also need to meet the express food and nutritional security and income generation needs of the local people [16]. Unfortunately, tree seedling establishment and survival in the Upper East Region are low due to the long dry season [17]. Native tree and shrub stumps have the advantage of established root systems that are more efficient in extracting nutrients and water from deeper horizons and hence stand a better chance of regenerating into trees than transplanted seedlings [18]. The presence of native tree and shrub stumps on a farmland is therefore an asset towards the regeneration of trees on farms. The presence of trees in agricultural landscapes has influential role in maintaining the health of ecosystems. Interestingly, farms in the Upper East region of Ghana, have few tree species resulting in poor ecosystem health [19]. The ecology of Northern Ghana is severely altered due to activities which remove trees from the landscape such as burning, intensive cultivation and unregulated grazing culminating in poor ecosystem health [20]. Furthermore, in 2008, [21] reported that, the savanna ecosystem of Ghana is rapidly deteriorating simply because of the removal of trees. This goes to affirm the general paradigm that, trees are important in maintaining ecosystem health. Diversity in the functioning of plants enhances ecosystem sustainability and this has important implications for agriculture [22]. Areas with high diversity of plants have been reported to have higher yield gains (both crops and non-crops) than simple crop monocultures [23]. Although the role of trees in maintaining ecosystem health is well known among ecologist, little or no work has been done in the Upper East region of Ghana in assessing the diversity of trees on agricultural landscapes. Since the usefulness of a tree species is an important incentive for its protection by local dwellers [24], the imperative is to identify the types of tree species that still remain on farms even in the face of the pressure to harvest them for the numerous competing uses, and establish a relationship between population density of trees on farmlands and the yield of the main crops cultivated in the area. Such information is expected to serve as a guide in the choice of tree species for numerous future agroforestry interventions that will impact on agricultural productivity and ecosystems.

2. METHODOLOGY

2.1 Study Area

The Upper East Region lies between longitude 0° and 1° West and latitudes 10° 30' N and 11° N. The region falls within the Sudan and Guinea Savannah zones of Ghana (Fig. 1). It is a generally degraded area as a result of the persistent annual bushfires, overexploitation of natural resources in the face of the ever increasing population. These conditions are contributed to mainly by the high levels of poverty in this part of the country. Rural savannah happens to be the poorest in Ghana, with more than half of its population classified as poor and more than a third classified as being very poor [25]. The population of the Upper East Region is about 1,046,545, with a population density of 118/km^2, the highest among the three northern regions [15]. The land is relatively flat with a few hills to the East and southeast and covers a total land area of about 8,842 km^2, which translates into 2.7 per cent of the total land area of the country. The climate is characterized by one rainy season from May/June to September/October. The mean annual rainfall during this period is between 800 mm and 1,100 mm. The rainfall is erratic spatially and in duration. There is a long spell of dry season from November to mid-February, characterized by cold, dry and dusty harmattan winds. Temperatures during this period can be as low as 14℃ at night, but can rise to more than 35℃ during the daytime. Humidity is, however, very low making the daytime high temperature very uncomfortable. This period is followed by very hot and sunny days with temperatures as high as 42℃ until the rains commence in May/June.

Soils of the study area are mainly savanna Ochrosols, Luvisols, Leptosols and Fluvisols. The Ochrosols are porous, well drained, loamy, slightly acidic and interspersed with patches of black and dark grey clay soils and are suitable for the cultivation of cereals and legumes.

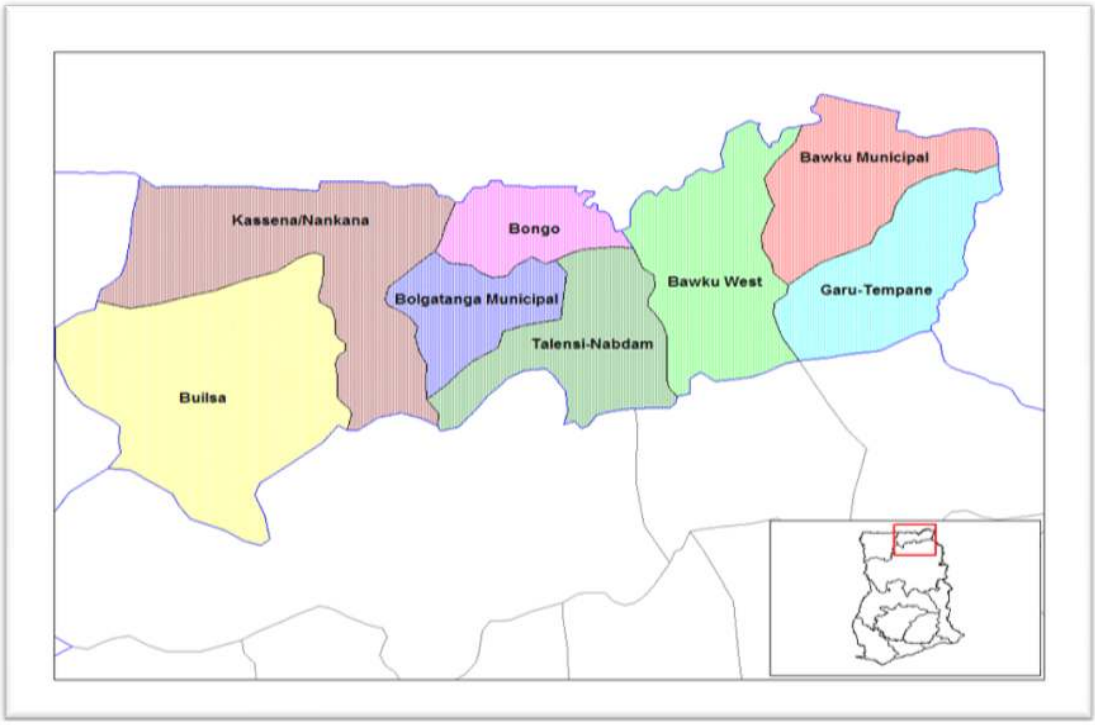

Fig. 1. Map of upper East Region of Ghana with the selected districts

The Luvisols, Leptosols and Fluvisols have light textured (sandy) surface horizons, with heavier textured (clayey) soils confined to valley bottoms [26]. Drainage is mainly by the White and Red Volta and Sissili Rivers [26]. The natural vegetation is characterized by short scattered drought-resistant trees and grasses that usually dry up after the long dry spell and serve as fuel for extensive bushfires.

The three districts have a short growing period which starts from June and ends in October. Garu-Tempane and Bawku West districts fall under the Sudan Savanna zone which is the driest zone in Ghana. The Kassena Nankana district on the other hand, falls under the Guinea Savanna zone of Ghana. Farmers in the study districts live in hamlets with an average farm size of 0.8 ha. The communities are characterized by mixed cropping with groundnut, maize, late millet, sorghum, cowpea, Bambara groundnut, vegetables and rice as the main crops. Rice is grown in low land areas while the other cereal and leguminous crops are cultivated in the uplands. Vegetable production occurs both in the short rainy season and also under irrigation in the long dry season. Most of the farmers in the study area raise cattle, goats, guinea fowl and chicken.

The commonest economic trees in the districts are the Sheanut (*Vitellaria paradoxa*), Dawadawa (*Parkia biglobosa*), Baobab (*Adansonia digitata*), Lannea, (*Lannea acida*), Tamarind (*Tamarindus indica*) and Apple ring tree (*Faidherbia albida*). Tree products such as shea butter and oil, shea nuts and spices from dawadawa are sold with the remaining used by the farmer household as food and beverages.

Three districts were randomly selected (Garu-Tempane, Bawku West and Kassena Nankana West). The respective communities are Tempane, Basyonde, Kugre and Akara-Teshie in the Garu-Tempane district, Boya, Sapaliga, Googo and Kokore in the Bawku West district and Boania, Navio, Badunu, and Mirigu in the Kassena Nakanna West district.

2.2 Data Collection

2.2.1 Farm inventories

Ten (10) farms were randomly selected from each of the four communities in the three districts and the farm sizes were measured using a hand held GPS device. 50 x 50 m plots were laid in each farm for tree inventory. The experimental plots were divided into five strips and teams of

two members each moved on the strips to ensure that all trees on the farm have been identified, counted and DBH measured using diameter tapes (all trees with dbh ≥10 cm). Identification of trees was done in collaboration with farmers (providing local names of the trees).

2.2.2 Interviews

Households were randomly selected from all the communities in the districts and semi-structured questionnaires/interviews administered to the heads of households [27,28]. A total of 802 farmers in the 12 sampled communities, within the three districts, were interviewed to elicit their views on the factors that influence their decisions to leave trees on farmlands, the attributes that determine whether a tree species will be allowed to grow on the farms or not and the average yield from their farms. In general, biodata of all farmers were collected during the interviews.

2.2.3 Data analysis

Qualitative data from questionnaire responses were analyzed with SPSS (Version 17) using ANOVA. Tree densities were statistically tested (with GenStat-12th Edition) using analysis of variance between communities and districts. Shannon Weiner index of diversity [29], evenness and species richness were also calculated for the three districts using GenStat-12th Edition. Tukeys HSD test was used (p = .05).

3. RESULTS

3.1 Density of Trees on Farmlands

Generally, every farm had a number of trees. There were however variations in the number of trees in each district ranging from 7.60 - 39.30, 2.60 - 34.30 and 9.20 - 51.80 trees per hectare for Garu Tempane, Bakwu West and Kassena Nankana West respectively. The highest number of trees was recorded in Badono in the Kassena Nankana West district (51.80 trees/ha). On the other hand, Boya in the Bawku West district recorded the lowest number of trees per hectare (2.62 trees/ha) (Fig. 2). The mean tree population density for the three districts is presented in Table 1. There were however, no significant differences in tree densities among communities as well as the districts (p = .05).

Table 1. Density of trees in the districts

Districts	Tree population/ha
Garu-Tempane	18.52 ±7.20[a]
Bawku West	18.40±7.15 [a]
Kassena Nankana West	25.88±9.26 [a]

± Standard error of the mean

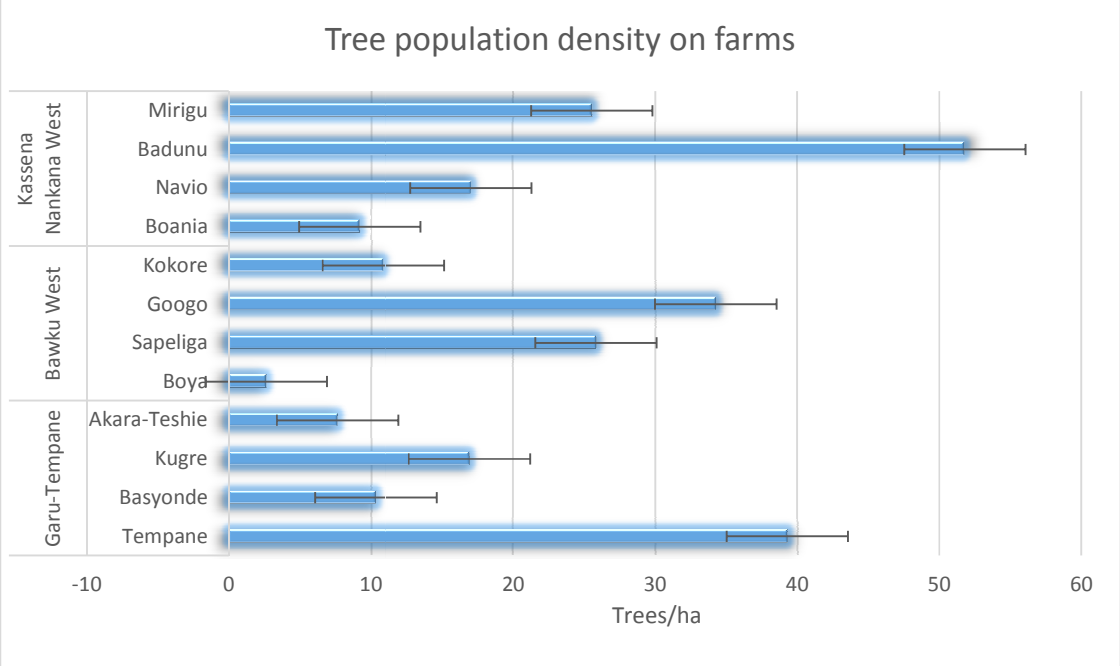

Fig. 2. Tree density per hectare for the farmlands

3.2 Tree Species Diversity on Farmlands

There were a wide variety of trees on farmlands. In the Garu - Tempane district, 42 different tree species belonging to 23 families were identified, 37 species from 21 families were identified in the Kasena Nankana West district while 28 species from 18 families were identified in the Bawku west district (Table 1).

Table 2. Number of tree species and the number of families on farmlands

District	No. of species	No. of families
Garu-Tempane	42	23
Bawku West	28	18
Kasena Nankana West	37	21

The most common tree species found in the three districts are *Azadirachta indica, Combretum molle, Diospyros mespiliformis.* These trees occurred on almost every farm that was sampled. The ten most common tree species encountered in the study area and their relative abundance are presented in Table 2. In terms of species richness, Garu-Tempane had the highest species richness although it is found in the driest zone (Table 1). Tree species were more even in the Kasana Nankana (0.418) and Garu-Tempane (0.429) districts. Species evenness was low at the Bawku West district (0.358).

Table 3. Common tree species and their relative abundance

Scientific name of trees	Relative abundance
Azadirachta indica	0.29
Combretum molle	0.22
Diospyros mespiliformis	0.18
Piliostigma thonningii	0.10
Jatropha curcas	0.06
Vitellaria paradosa	0.05
Mangifera indica	0.04
Acacia dudgeon	0.03
Acacia sieberiana	0.02
Tectona grandis	0.01

The highest Shannon-Weiner index of diversity was found in Gbantongo (1.938) in the Bawku West district followed by Basyonde (1.773) in the Garu-Tempane district. The lowest species diversity index was found in Googo (0.083) in Bawku West district. In general, high diversity index was recorded in the Garu-Tempane district. The Kassena Nankana West district recorded the second highest diversity index although there was no significant difference between them (Table 3).

Table 4. Species diversity index of tree species in the three districts

District	Diversity index
Garu-Tempane	1.563[a]
Bawku West	1.195[a]
Kassena Nankana West	1.551[a]

[a] *no significant difference between the districts*

3.3 Reasons for Allowing Trees on Farmlands

A total of 802 respondents were interviewed in the three districts with 277, 246 and 279 respondents from Garu-Tempane, Bawku West and Kassena Nankana West districts respectively (Fig. 3). The variation in the number of respondents from the district is as a result of the farmer population in the sampled communities.

The commonest reasons among respondents for leaving trees on farmlands were for the provision of shade, fuelwood, food source, medicine, housing, soil fertility, erosion control, fodder and only 3.5% leaving trees for bee forage, purposes of deity and aesthetic value (others). The respective responses for the above mentioned purposes are presented in Fig. 4. Out of the 802 respondents, 63.6% were males wheras 36.4% were females. Although, all respondents are into farming, only 89.1% have farming as their primary occupation. Even though livestock production is an important economic agricultural activity, the retention of trees as sources of fodder was not considered important due to the traditional "free range" system where livestock are allowed to roam and browse on fields during the dry season.

3.4 Yield of the Popular Crops in the Districts

Farmers in the Bawku West district, produced the highest quantity of groundnut, maize, millet and sorghum per unit area. In general, crop yields in the Garu-Tempane district are low compared to the other two districts. The Kassena Nankana West district also had the second highest yield for almost all the five crops. The yields of the five most cultivated crops are presented in Table 5. There were significant differences between the crops in all the three districts (p= .05).

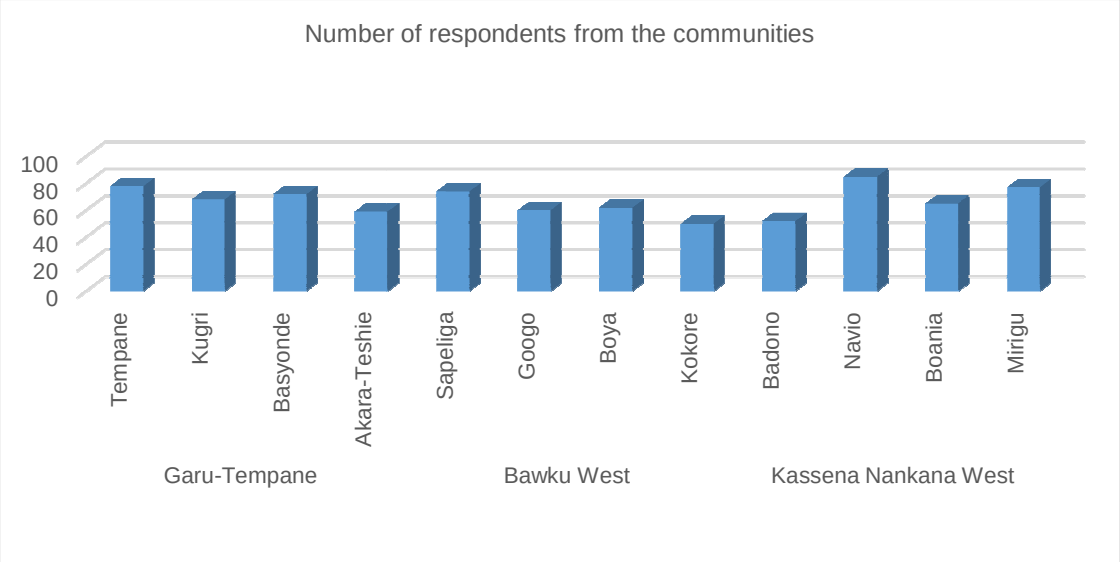

Fig. 3. Number of respondents from the study communities

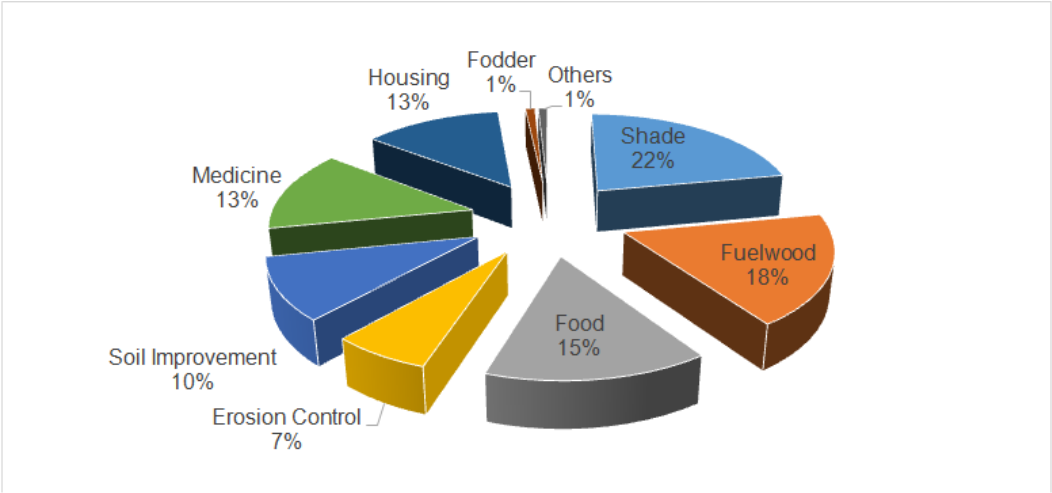

Fig. 4. Purpose for leaving trees on farms

Table 5. Yield of crops in the districts

District	Yield (tons/ha)					
	Tree density	Groundnut	Maize	Millet	Sorghum	Cowpea
Garu-Tempane	18.5	0.600±0.022 [a]	1.416±0.029 [b]	0.892±0.089 [a]	0.600±0.017 [a]	0.800±0.036 [a]
Bawku West	18.4	1.195±0.057 [b]	1.690±0.045 [c]	1.222±0.033 [b]	1.300±0.092 [b]	0.828±0.063 [a]
KN West	25.9	0.990±0.086 [b]	1.222±0.033 [a]	1.104±0.071 [b]	1.210±0.028 [b]	1.502±0.139 [b]
r value		0.165	-0.819	0.151	0.383	0.999

The correlation between yield of cowpea and tree population density showed a strong positive relationship. On the other hand, the relationship between maize and tree population density was

negative but a strong one. The others showed a positive but weak relationship with tree population density (Table 5).

4. DISCUSSION

4.1 Tree Densities on Farmlands

The study revealed that the population densities of trees on farmlands in the study communities (2- 52 trees per hectare) is a far cry from the numbers in areas where active interventions were made to enable trees make significant contributions towards improved agricultural productivity. Nonetheless, this is in line with the findings of [30] who found an average of 10 trees/ha in northern Ghana. Similarly, [31] also found 1-7 trees/ha in the Savanna zone of Benin. Conversely, in Niger, farmers, after being convinced of the contributions of *Faidherbia albida*, could have up to 150 trees per hectare on farmlands [32]. These low tree population densities can be attributed to the numerous uses of tree resources including fuelwood, housing materials, forage for livestock, medicine coupled with the high human population density leading to a high rate of exploitation [33]. Moreover, there is the general belief that trees compete with field crops for resources like nutrients, water, sunlight and space thereby reducing crop yields [34]. This perception could also account for the low tree density on farmlands in the selected communities.

Now in the era of climate change with its associated soaring temperatures especially in the study area, there is the need for trees on agricultural landscapes to help minimize evapotranspiration rates as well as contribute to climate change mitigation. Trees on crop lands make the agro-ecosystem more resilient to the excessively harsh environmental conditions [35].

4.2 Tree Species on Farmlands

The highest diversity index of 1.563 for the Garu-Tempane district can be compared to the diversity index reported by [31]. In 2008, Ouinsavi and Sokpon recorded a diversity index of 2.9 in the Guineo-Congolean zone in Benin. The difference in species diversity index could be attributed to the more humid conditions in their study area in Benin and also the increasing high pressure on trees in Northern Ghana. Similarly, the number of species we encountered in the study area (42 species, 23 families) is in line with the findings of [31] who also encountered 45 species belonging to 24 families in Benin. This implies that, although the study districts are drier, they can still accommodate quite a number of tree species if sustainable management of trees is adopted.

Comparing the total number of tree species in the study area to a similar zone in Nigeria, [36] encountered 51 species belonging to 27 families whereas we enumerated 30 species belonging to 23 families. The difference could be accounted for by the rampant bush fires in northern Ghana. The use of wood/tree products for local housing in our study area which reflected in the reasons for allowing trees on farmlands (Fig. 4) could be a key reason for the differences.

4.3 Reasons for Leaving Trees on Farmlands

[37], pointed out that, a clear understanding of farmers' incentives and livelihood strategies within the socio-economic and policy environment are the pre-requisites for any successful rural development intervention that involves on-farm tree planting. When respondents were asked to state attributes of trees that would normally urge them to maintain trees on their farms, it turned out that those that provide shade were the most commonly mentioned (Fig. 3). Almost every farmer would leave one or two trees on his or her farm due to its ability to provide shade. This is necessary because of the fact that for most parts of the year the days are very sunny with high temperatures. Farmers would therefore need shady places to rest in such conditions and also reduce moisture loss from both the soil and plants. In a similar work, [38] mentioned fodder as the main reason/purpose for which farmers leave trees on croplands. Likewise, [39] reported that, shade and soil improvement were the reasons famers mentioned for leaving trees on croplands. Farmers in the savanna region of Nigeria said food and fodder were their priority for having trees on their farms [36]. Our findings affirm those mentioned above as the reasons also appears to be why farmers leave trees on their farms (Fig. 3).

Moreover, tree based food is a very important source of household nutrition especially in the lean season. Fruits, seeds, fresh leaves are the commonest tree parts that are consumed in most households in northern Ghana. Some are consumed in their fresh forms while others are used as condiments in foods and others in the

preparation of local drinks. Trees like *Lannea acida, Mangifera indica, Diospyros mespiliformis, Parkia biglobosa, Tamarindus indica, Vitelaria paradoxa, Vitex doniana* are some important trees considered for their contribution to household nutrition. The use of trees for soil improvement seems to be quite remote. Even though trees could contribute to soil fertility, farmers do not consciously maintain trees purposely for that [39].

4.4 Yield of the Commonest Crops in the Districts

Generally, yield of the five crops in the study districts were high (Table 5) compared with the regional averages reported by [40]. Comparing the three districts, Garu-Tempane recorded the lowest yield for almost all the crops although the output was in the same level as the regional average. The low yields in the Garu-Tempane district, can be attributed to the low rainfall, poor soils and farmers' inability to afford fertilizers [41]. Moreover, comparing the yields from the study districts/Upper East region to the Upper West and Northern region of Ghana, the yields for the five main crops were higher in the study area [40].

The strong but negative relationship between maize and tree population density, is an indication that maize is not a shade tolerant crop and as such, the yield decreases where the tree density was high [42]. Looking at the common tree species in Table 3, only a few of the trees improve soil fertility and such trees had a lower relative abundance. The trees only serve as shade trees which limits the yield of maize [34]. Conversely, the yield of cowpea had a strong positive linear relationship (r=0.999) with tree population density. The cowpea cultivated in the study areas are the local creeping varieties which tolerate shade. However, the rest of the crops (Sorghum, millet and groundnut) showed a positive but weak relationship with tree population density (Table 5).

5. CONCLUSION AND RECOMMENDATION

Although there is intense pressure on tree resources in the study area, there are still a considerable number of trees on farmlands. Findings of the study indicated that trees are left on farmlands for a wide variety of purposes and this accounts for the wide diversity of tree species found on farmlands. The probability of a tree being found on a farmland therefore depends on the farmer's perception of its utility value. The contribution of trees to soil fertility was not considered as a priority but mostly as an unintended effect. Tree population on the farm alone might not contribute to soil fertility improvement but rather the type of trees on the farm. Most of the trees found in the farms were not nitrogen fixing trees/soil improvement culminating in only 10% of the responses supporting trees for soil improvement. Moreover, the Bawku West district with the lower tree species diversity recorded the highest yield of almost all the five commonly cultivated crops.

There is therefore the need for more on-farm demonstrations to convince the farmer of the capabilities of trees in improving upon soil fertility and hence crop productivity. From the study, farmers have a very strong influence on the types of tree that grow on their farmlands and as such, their involvement in the choice of trees for agroforestry technologies should be taken very seriously at the planning and implementation levels. Adopting a "learning by doing" approach will encourage farmers to incorporate soil improving trees on farmlands. This will make the agroecosystem more resilient to the changing climate and impact positively on biodiversity conservation and also improve upon soil fertility.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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