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Diversity of tree species in cultivated and fallow fields within Shea Parklands of Ghana

F. A. Chimsah[1*], G. Nyarko[1], J. A. Yidana[1], A-H. Abubakari[1], G. K. Mahunu[1], F. K. Abagale[2], A. Quainoo[3]

[1]*Department of Horticulture, University for Development Studies (UDS) Box TL 1882 Tamale, Ghana*

[2]*Departmnet of Agricultural Mechanization and Irrigation Technology, University for Development Studies (UDS) Box TL 1882 Tamale, Ghana*

[3]*Department of Biotechnology. University for Development Studies (UDS) Box TL 1882 Tamale, Ghana*

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Abstract

Tree species diversity associated with shea in cultivated and fallow fields of shea parklands of Ghana was studied. The study was to assess tree species diversity in relation to land use type across a North – South gradient of shea growing sites in Ghana. The study was conducted in 2011/12 at Paga, Nyankpala and Kawampe. In addition to shea trees, other highly valued tree species are preserved in parkland systems because of their ability to improve soil fertility and increase crop yield In addition to reducing microclimatic extremes as well as wind and water erosion, parkland trees are important sources of income and nutritional security. There is the need to conserve other tree species so as to reduce the over reliance on shea tree as the sole economic tree in many areas of the savanna parkland. Fifty four (54) quadrats measuring 50 x 50 m (18 in each location) were used as experimental plots. Diversity of higher woody plants was analyzed using the Simpson Diversity Index (*D*). A total of 863 trees were studied. The total density of trees in cultivated and fallow fields was 64 and 355 for Paga, 39 and 130 for Nyankpala, 75 and 200 for Kawampe. Shea densities in all the study locations showed that there were more shea trees in fallow fields (469) than cultivated fields (298). The main species identified in the study were *Diospyros mespiliformis* Hochst, *Annona senegalensis* Pers, *Azadirachta indica* A.Juss, *Terminalia albida* Sc Elliot and *Senna siamea* Lam. The occurrence of these species amounted to 54.8% of all trees. Fallow fields were more species composed (33 species) than cultivated fields (21 species). The results showed differences in diversity based on locations with Paga and Nyankpala showing high species diversity of 0.95 each in cultivated and fallow fields. However, there were no significant differences (P >0.05) in species diversity of all three study locations within cultivated and fallow fields.

***CorrespondingAuthor:** Chimsah Francis Azumah ✉ chimsah2000@yahoo.com

Introduction

Biodiversity can be also defined as the kinds and numbers of organism and their patterns of distribution (Barnes *et. al.,* 1998). Moreover, diversity has become an increasingly popular topic within the discussion of sustainability in the last decade, though the maintenance of diversity of forest ecosystems has been in practice for many years (Schuler, 1998; Swindel *et. al.,* 1984).

Biodiversity conservation relies on understanding how plant resources are distributed across complex landscape and modifield for human livelihoods (Cunningham 2001). In order to conserve maximum range of regional biodiversity better understanding of vegetation dynamics at spatio-temporal scale and successional trends would be required (Adler and Lauenroth 2003; Tilman 1999).

The most extensive vegetation type in Ghana is the Guinea Savanna. It is estimated to cover about 60.77% of the total land area of Ghana (Anounymous, 2002). Documented studies on the Guinea Savanna of Ghana dates back to Vigne (1936), Taylor (1952), Backer (1662), Lawson *et al.,* (1969), Houssain and Hall (1969), Hopkins (1979) and recently Asase and Oteng-Yeboah (2007). It is in no doubt that Ghana is rich in biodiversity stemming from its coast through to the forest and transitional belt all through to the Savanna regions.

The shea tree (*Vitellaria paradoxa*), or *karité* in French, is a wild fruit tree indigenous to the semi-arid and sub-humid savannas of sub-Saharan Africa. In recent years the shea tree has gained importance as an economic crop because of the heavy demand for its butter both locally and internationally.

Vitellaria paradoxa grows naturally in the wild in the dry savanna belt of West Africa from Senegal in the West to Sudan in the East and onto the foothills of the Ethiopian highlands. It occurs on an estimated 1 million km^2 between Senegal and Northern Uganda, where annual rainfall ranges from 500 to 1200mm (Salle *et al.,* 2001). FAO, 1988, stated that, it occurs extensively in the Guinea savannah and less abundantly in the Sudan savannah. It is generally believed to be the most frequently found species in the Guinea savannah zone (Brain, 1992).

Extensive studies have being done by Jean-Marc (1999) that covers the shea parkland systems from a Sub-Saharan Africa regional perspective. Much study have also addressed the ethnobotany of *Vitellaria* in the broader context of the parkland system, in which the tree is one (very significant) savanna woodland species of many which provide sustainable rural livelihoods to communities across the shea zone. A particularly extensive parkland ethnobotany, for Ghana, is Abbiw (1990).

Studies have been conducted on the diversity of *Vitellaria paradoxa* including collection of germplasm in Ghana (Adu-Ampomah *et al.,* 1995, Lovett and Haq, 1999a), and in Burkina Faso, Mali, Senegal and Uganda supervised by the International Centre for Research in Agroforestry (ICRAF).

The main aim of this study was to assess the diversity of associated tree species within shea parklands across the ecological zones of shea growing areas in Ghana. With this, the study sought to assess these diversities within two field types of cultivated and fallow.

Relevance of tree species in shea parklands

According to Masters, (2002) It has been commonly observed across the African shea zone that the shea tree yields best– and earliest – when it is protected by cultivation. Throughout the region, shea tree densities are closely linked to human populations (or *vice versa*). In fallow, the incidence of protected trees of different species of various sizes indicates a strong correlation between conservation and the productive value of a given species.

Boukoungou, (2002) stated that farmers in the African Region preserved shea valuable resource by integrating shea trees (and other useful trees) and annual crops. The system has worked well in the past, but it is now breaking down under increased human population pressure. Shea trees are ageing, natural regeneration is impeded by excessive reduction of fallow periods, vigor and fruit production of many adult trees are reduced because of frequent attacks by plant parasites, viz. *Tapinanthus* spp.

Boukoungou, (2002) stated that farmers across the shea belt at the time of land clearing for agricultural production, farmers did not cut all trees. They preserved valuable species such as *Vitellaria paradoxa* and nurtured them in the cropped field. In addition to shea trees, other highly valued tree species preserved in parkland systems include fruits trees such as dawadawa or néré (*Parkia biglobosa*), tamarind (*Tamarindus indica*), baobab (*Adansonia digitata*) or the mythical tree (*Faidherbia albida*) because of its well-recognised ability to improve soil fertility and increase crop yield. The 'anthropic' parklands system now forms an integral and often dominant part of the natural and agricultural landscapes in which the tree grows. In addition to reducing microclimatic extremes as well as wind and water erosion, parkland trees are important sources of income and nutritional security, producing fruits, fat, spices, etc. that are used domestically or sold for cash. Yet, the parkland system has long been neglected by modern science and rural development agents, falling in the crack between foresters and agronomists. Foresters have traditionally focused on natural forests or plantations, with little consideration for trees in crop fields, while agronomists have considered trees to be outside their mandate.

There is increasing evidence that the yield and quality of shea butter are not determined by processing techniques alone. Tree traits are important determinants of butter characteristics. Continued degradation of the resource base therefore will not only affect the volume of supply, but will also affect quality aspects related to disappearing intra-species biodiversity.

However, much has not being researched into the inter species diversity and relationship with shea parklands in Ghana. A better understanding of the plant biodiversity within shea parklands would aid in understanding the population, structure and composition of closely related species with the shea, this could help reduce the over reliance of the shea tree as a source of product other than it's economic value which is essential for alleviating poverty in rural areas.

There is the need for the shea industry to expand its programmes and projects beyond processing and marketing to stress the critical issues of protection and improvement of the resource base that includes other tree species within the shea ecology. Based on these and other factors, this paper aims to highlight the importance of shea trees and shea parklands in Ghana, by documenting the inter-species biodiversity of shea parklands with other tree species in fixed plots under cultivated fields and fallow fields and describing the species composition (species richness and diversity).

Materials and methods

The study was carried out between 2010 and 2011 in three shea parklands of Ghana namely Paga, Nyankpala and Kawampe. The study locations were selected covering the climatic zones on the North-South gradient of the shea growing areas in Ghana the sites fall within the Guinea Savanna and Transitional belt of the vegetational zone of Ghana.

Paga: Located between latitude 10° 57.225 N and longitude 01° 04,720 W. Paga located in the North Eastern part of Ghana. It in the Paga-Chiana District of the Upper East Region. The Agro-ecological zone of the area is Sudan Savanna

Nyankpala: Located between latitude 09° 25.925 N and longitude 01° 00,420 W. The area is in the

Tolon-Kumbungu District of the Northern Region of Ghana. The Agro-ecological zone of the area is Guinea Savanna.

Kawampe: Located between latitude 08° 25.630 N and longitude 01° 33,550 W. The area is in the Kintampo North District of the Brong Ahafo Region of Ghana. The area falls within the transitional belt of the Northern Savanna and the Southern Forest.

In each site, shea parklands under two land use type, i.e., cultivated field and fallow fields were selected using established permanent plots. For each land use type, three land ages were considered: The Land ages were classified as follows:

New (N) – a land use age type that is between 1-5 years (e.g. field being cultivated between 1-5 years or the land left fallow between 1-5 years)

Medium (M) – a land use age type that is between 6-10 years

Old (O) – a land use age type that is more than 10 years

For the land use ages, three (3) replicate permanent plots were established in each location of given age for each land use type. 9 each for each land use type i.e cultivated field and fallow fields. This gave a total of 18 plots in each site (Paga, Nyankpala and Kawampe) making up a grand total of 54 plots.

For the 54 plots, 50 x 50 m (0.25ha) quadrats were laid in each field, with a minimum distance of 200m between fields in a particular site/location.

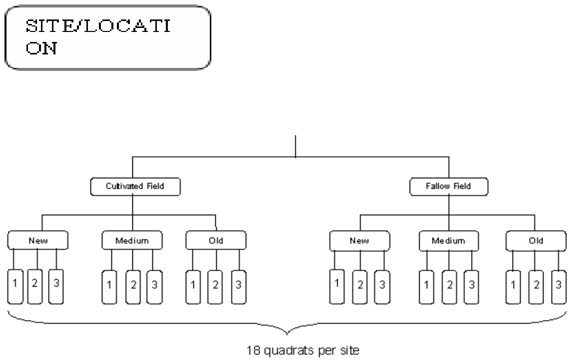

Table 1. Comparism of shea tree density and other tree densities in the Shea parkland.

LOCATION	TREE DENSITY IN CULTIVATED FIELDS	A	TREE DENSITY IN FALLOW FIELDS	B	
	Shea trees	Other Species	Shea trees	Other Species	Total (A+B)
PAGA	64	64	85	355	**419**
NYANKPALA	136	39	262	130	**169**
KAWAMPE	98	75	122	200	**275**
TOTAL	**298**	**178**	**469**	**685**	

Table 2. Simpson's index for cultivated and fallow fields.

LOCATION	CULTIVATED FIELDS		FALLOW FIELDS	
	Simpson's Index of Diversity (D)	Simpson's Reciprocal Index	Simpson's Index of Diversity (D)	Simpson's Reciprocal Index
PAGA	0.94	17	0.86	7
NYANKPALA	0.88	9	0.94	16
KAWAMPE	0.81	5	0.85	6

Table 3. Tree species diversity in cultivaled and fallow fields.

	CULTIVATED FIELD			FALLOW FIELDS		
	Species Composition	Tree Density	Diversity Index (D)	Species Composition	TreeDensit y	Diversity Index(D)
PAGA	5	64	0.94	13	355	0.86
NYANKPALA	7	39	0.88	9	130	0.94
KAWAMPE	9	75	0.81	11	200	0.85
	21	**178**		**33**	**685**	

Table 3 below shows a summary of results obtained from the study on diversity parameters across the two fields in all three locations. The table shows and compares the species composition of all individual species identified, the number of individual species counted (richness) and the species diversity index.

Data analysis

The number of individuals of each tree species per field location was calculated from the total number of individuals of the species recorded in the 54 quadrats. Diversity of higher woody plants was analysed using the Simpson Diversity Index (*D*). These indices are considered as a measure of species dominances (Magurran, 1988).

Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species).

D is represented mathematically as: $D = \sum (n / N)^2$

Where: n = the total number of individual species in a field or location

N = the total number of all species in the study area

However, to calculate the Simpson's Index of Diversity, the value of D which ranges from 0 -1 is subtracted from 1 (1 – D). This therefore means that the greater the value, the greater the sample diversity.

Another way of making Simpson's Index of Diversity clearer is to take the reciprocal of the Index. Simpson's Reciprocal Index 1 / D

The value of this index starts with 1 as the lowest possible figure. This figure would represent a location containing only one species. The higher the value, the greater the diversity, the maximum value is the number of species in the sample. For example if there are five species in the sample, then the maximum value is 5.

Results and discussion

Species Density

The density (number of individual species per location) of tree species recorded in the three study locations varied among species. This does not take into account the proportion and distribution of each subspecies within a zone. In all the three location (Paga, Nyankpala and Kawampe) and the two main fields (cultivated fields and fallow fields), a total of 863 plant species were studied. The total density of tree species in cultivated and fallow fields was 64 and 355 for Paga, 39 and 130 for Nyankpala, 75 and 200 for Kawampe. Shea densities from the study showed that there were more shea trees in fallow fields (469) than cultivated fields (298). Across fields it was noted that Nyankpala located within the middle part of shea growing parklands of Ghana had more shea trees than the other locations.

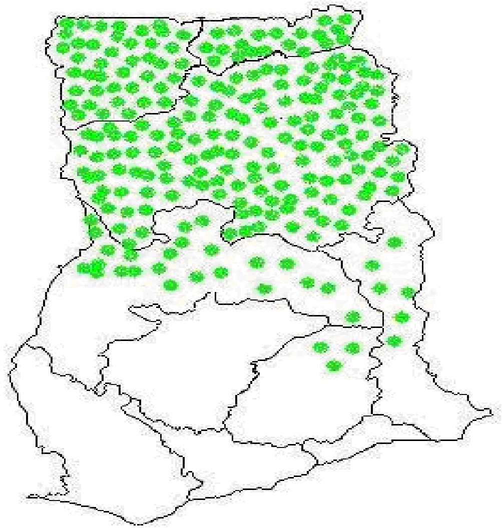

Fig. 1. Map of Ghana showing shea growing areas and study sites

Species with the highest densities in the three locations were, in descending order of density, *Diospyros mespiliformis* Hochst, *Annona senegalensis* Pers and *Azadirachta indica* A. Juss for species in cultivated fields whiles *Diospyros mespiliformis* Hochst, *Terminalia albida* Sc Elliot and *Senna siamea* Lam for species in fallow fields.

Species Composition and Abundance

The study areas were mainly (54.8%) abundant with the following species: *Diospyros mespiliformis* Hochst, *Annona senegalensis* Pers, *Azadirachta indica* A. Juss, *Diospyros mespiliformis* Hochst, *Terminalia albida* Sc Elliot and *Senna siamea* Lam. Species density from the study area clearly showed that Paga obtained a significantly high species density for fallow fields. However, an examination on the species composition for Paga showed that 67% of the species recorded was *Diospyros mespiliformis* Hochst. In the three study locations, fallow fields were more species composed (33) than cultivated fields (21 species).

Fig. 2. Photos of both cultivated field and fallow fields.

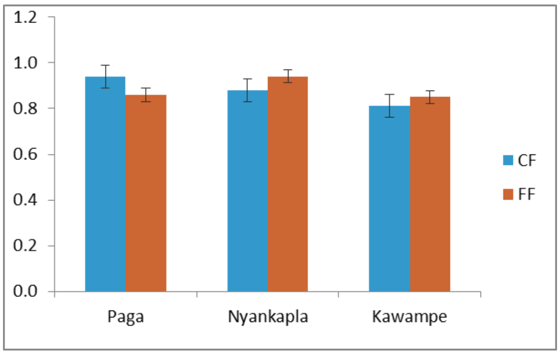

Fig. 3. Diversity Index (D) for cultivated fields and fallow fields.

All species identified in both cultivated and fallow fields in the study area represented 16 families. The most species diverse families were Mimosoideae (4 species), Combretaceae and Caesalpinoideae (3 species each). 13 other families were represented by less than two species.

Species Diversity

Simpson's Diversity Index is a measure of diversity which takes into account both richness and evenness. Evenness is a measure of the relative abundance of the different species making up the richness of an area. As species richness and evenness increase, so diversity increases. Table 2 shows the results from computing Simpson's Index of Diversity (1-D) and Simpson's Reciprocal Index (1/D)

The value of 1-D range from 0 – 1 where the greater the value the greater the sample diversity. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species.

The value of 1/D starts with 1 as the lowest possible figure. This figure would represent a location field type containing only one species. The higher the value, the greater the diversity. The maximum value is the number of species in the sample. For example if there are five species in the sample, then the maximum value is 5.

The results show that within cultivated fields, high value of Diversity (D) was recorded in Paga (0.94) followed by Nyankpala (0.88) and Kawampe (0.81). For fallow fields, high Diversity value was recorded in Nyankpala (0.94) followed by Paga (0.86) and Kawampe (0.85).

The results shows Kawampe with high species densities in some fields but recording least species diversity index, this could be attributed to the fact that majority of the trees recorded within that location belong to fewer species. According to Roth *et al.,* (1994) diversity indices provide more information than simply the number of species present (i.e., they account for some species being rare and others being common).

There was no significant differences (P >0.05) in species diversity observed in all three study sites within cultivated and fallow fields as shown in figure 3 below.

For Simpson's Reciprocal Index, the value for each location indicates the level of diversity for each given location. The value ranges from the minimum as the number of species composition to the maximum as the total number of species.

Conclusion

The study and research into the diversity of tree species in shea parklands is as important as managing the shea tree itself. This study which focused on shea parklands in the North – South gradient of shea growing areas of Ghana examined the diversity across the gradient in cultivated and fallow fields of shea parklands. In Ghana, shea is found growing in fallow fields or on farmers cultivated fields.

Insects such as bees are the main pollinators of shea flowers. The yield of shea is mostly influenced by rate of pollination. The availability of flowers in shea and other associated tree species would greatly affect the rate of pollination by attracting insects this would therefore affect the yield of the shea tree. Yield of shea vary considerably from one location to another however, realistic generalization ranges from 15-30 kg of fresh fruits per tree per year (Adomako, 1989).
The study showed that in all three locations (Paga, Nyankpala and Kawampe) fallow fields are more species rich than cultivated fields. The results showed varied differences in diversity based on locations with Paga and Nyankpala showing high species diversity in cultivated and fallow fields respectively. Generally, Paga located in the North most part of the North-South gradient of shea growing areas in Ghana obtained a significantly high species density for fallow fields though most (67%) the species was *Diospyros mespiliformis* Hochst.
Mimosoideae, Combretaceae and Caesalpinoideae families were the most common families associated with shea. The common species identified included *Diospyros mespiliformis* Hochst, *Annona senegalensis* Pers and *Azadirachta indica* A. Juss , *Terminalia albida* Sc Elliot and *Senna siamea* Lam. These species constituted 54.8% of all tree species recorded in the study area.

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Appendix 1. List of tree species identified.

LOCATION	Species	Family	SPECIES DENSITY Cultivated Field	Fallow Field
PAGA				
1	*Terminalia albida* Sc Elliot	Combretaceae	-	34
2	*Terminalia mollis* Laws	Combretaceae	5	56
3	*Faidherbia albida* Del	Mimosoideae	-	2
4	*Parkia biglobosa* Jacq	Mimosoideae	-	1
5	*Acacia sieberiana* DC	Mimosoideae	-	1
6	*Diospyros mespiliformis* Hochst	Ebenaceae	53	240
7	*Annona senegalensis* Pers	Annonaceae	2	2
8	*Sterculia spp* Del	Sterculiaceae	-	2
9	*Bombax costatum* Pellegr&Vuillet	Bombacaceae	-	1
10	*Azadirachta indica* A. Juss	Miliaceae	3	13
11	*Gardenia aqualla* Stapf&Hutch	Pubiaceae	1	-
12	*Lannea acida* A.Rich	Anacardiaceae	-	1
13	*Eucalyptus tereficornis* Hook	Myrtaceae	-	1
14	*Tamarindus indica* L.	Caesalpinoideae	-	1
			64	355
NYANKPALA				
1	*Azadirachta indica* A. Juss	Miliaceae	13	27
2	*Combretum collinum* Fresen	Combretaceae	1	15
3	*Parkia biglobosa* Jacq	Mimosoideae	11	7
4	*Anacardium occidentale* L.	Anacardiaceae	7	17
5	*Senna siamea* Lam	Caesalpinioideae	-	44
6	*Strychnos spinosa* Lam	Longaniaceae	-	2
7	*Diospyros mespiliformis* Hochst	Ebenaceae	-	10
8	*Albizia lebbeck* (L.)Benth	Mimosoideae	-	1
9	*Gardenia aqualla* Stapf&Hutch	Pubiaceae	-	7
10	*Sterculia spp* Del	Sterculiaceae	1	-
11	*Ficus sycomorus subsp.gnaphalocarpa* Miq.	Moraceae	3	-
12	*Acacia sieberiana* DC	Mimosoideae	3	-
			39	130
KAWAMPE				
1	*Annona senegalensis* Pers	Annonaceae	50	38
2	*Khaya senegalensis* (Desr) A. Juss	Miliaceae	5	12
3	*Parkia biglobosa* Jacq	Mimosoideae	1	7
4	*Terminalia albida* Sc Elliot	Combretaceae	1	73
5	*Terminalia mollis* Laws	Combretaceae	-	34
6	*Gardenia aqualla* Stapf&Hutch	Pubiaceae	1	2
7	*Acacia sieberiana* DC	Mimosoideae	2	11
8	*Albizia lebbeck* (L.)Benth	Mimosoideae	1	1
9	*Detarium microcarpum* Guill&Perr	Caesalpinoideae	-	2
10	*Daniella olivera* (Rolfe) Hutch&Dalz	Caesalpinoideae	-	16
11	*Piliostigma thonningii* Schumach	Caesalpinoideae	3	2
12	*Anacardium occidentale* L.	Anacardiaceae	11	1
13	Tectona grandis L.F.	Verbenaceae	-	1
			75	200