THE POTENTIAL OF COCOA-BASED AGROFORESTRY SYSTEMS FOR TREE RESOURCE CONSERVATION AROUND THE DJA BIOSPHERE RESERVE SOUTHEASTERN CAMEROON.

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Abstract

Agroforestry is considered as a promising buffer zone agricultural practice that can both conserve biodiversity, reduce pressure on tree resources in protected areas while at the same time support the livelihoods of the surrounding populations. The objective of this study was to evaluate tree species diversity, structure and conservation status of these tree species in cocoa-based agroforestry systems around the Dja Biosphere Reserve, South Eastern region of Cameroon. A random sampling approach was adopted, whereby, 100 plots of 100 m x 20 m and 10 m × 20 m were laid down in cocoa agroforestry systems on a total surface area of 18.02 hectares. In each plot, all tree species were identified, counted and their diameter at breast height and height were measured. These data were used to assess parameters such tree species density, basal area, importance value index and Shannon diversity index of cocoa-based agroforestry systems in the four clusters around the Dja Biosphere Reserve. A tree abundance of 1582 was recorded in all the four clusters representing 67 species and 63 genera belonging to 29 families. Species richness was lowest in the East cluster (30) and highest in the west cluster (50). Shannon diversity index varied from (3.39) for the West cluster and (2.95) for the east cluster. Mean basal area varied from 11.72 m² for the North cluster and 12.21 m² for the South cluster. Mean density varied from 108 stems/ha for the North cluster and 113 stems/ha for the South cluster. Terminalia superba had the highest important value index for the East cluster (47.6 %) and South cluster (22.9 %) and Ricinodendron heudelotii for the West cluster (31.78 %) and the North cluster (41.7 %). ANOVA test indicates significance difference ($p \geq 0.05$) for tree species density between clusters and Turkey test shows that this significance difference was between the East and North cluster. However no significance difference was observed for basal area between the four clusters. 30 % of tree species found in cocoa-based agroforestry systems were listed on the red list of plants species, indicating the contribution of these cocoa agroforestry systems in conserving vulnerable and threatened tree species of the Dja Biosphere reserve. The study concluded that cocoa agroforestry systems around protected areas could serve as reservoirs for biodiversity conservation if managed effectively.
Key words: *Tree, species, conservation, diversity, cocoa, agroforestry system.*

Résumé

L'agroforesterie est considérée comme une pratique agricole de zone tampon prometteuse qui peut à la fois conserver la biodiversité, réduire la pression sur les ressources forestières dans les zones protégées tout en soutenant les moyens de subsistance des populations environnantes. L'objectif de cette étude était d'évaluer la diversité, la structure et l'état de conservation des espèces d'arbres dans les systèmes agroforestiers à base de cacao autour de la réserve de biosphère du Dja, région du sud-est du Cameroun. Une approche d'échantillonnage aléatoire a été adoptée, selon laquelle 100 parcelles de 100 m × 20 m et 10 m × 20 m ont été aménagées dans des systèmes agroforestiers cacaoyères sur une superficie totale de 18,02 hectares. Dans chaque parcelle, toutes les espèces d'arbres ont été identifiées, comptées et leur diamètre à hauteur de poitrine et à hauteur mesurées. Ces données ont été utilisées pour évaluer des paramètres tels que la densité des espèces d'arbres, l'abondance et la surface terrière ainsi que l'indice de valeur d'importance et l'indice de diversité de Shannon des systèmes agroforestiers à base de cacao dans les quatre groupes autour de la réserve de biosphère du Dja. Une abondance d'arbres de 1582 a été enregistrée dans les quatre grappes représentant 67 espèces et 63 genres appartenant à 29 familles. La richesse en espèces était la plus faible dans la grappe Est (30) et la plus élevée dans la grappe ouest (50). L'indice de diversité de Shannon variait de (3,39) pour le groupe Ouest et (2,95) pour le groupe est. La surface terrière moyenne variait de 11,72 m2 pour le cluster Nord et 12,21 m2 pour le cluster Sud. La densité moyenne variait de 108 tiges / ha pour la grappe Nord et 113 tiges / ha pour la grappe Sud. Terminalia superba avait l'indice de valeur importante le plus élevé pour le cluster Est (47,6%) et Sud (22,9%) et Ricinodendron heudelotii pour le cluster Ouest (31,78%) et le cluster Nord (41,7%). Le test ANOVA indique une différence de signification ($p \geq 0,05$) pour la densité des espèces d'arbres entre les grappes et le test de Turquie montre que cette différence de signification était entre les grappes Est et Nord. Cependant, aucune différence significative n'a été observée pour la surface terrière entre les quatre grappes. 30% des espèces d'arbres trouvées dans les systèmes agroforestiers à base de cacao ont été inscrites sur la liste rouge des espèces végétales, indiquant la contribution de ces systèmes agroforestiers cacaoyères à la conservation des espèces d'arbres vulnérables et menacées de la réserve de biosphère du Dja. L'étude a conclu que les systèmes agroforestiers du cacao autour des aires protégées pourraient servir de réservoirs pour la conservation de la biodiversité s'ils sont gérés efficacement.
***Mots clés**: arbre, espèce, conservation, diversité, cacao, système agroforestier*

1. Introduction

Agroforestry systems, where crops such as cocoa are cultivated with associated plants are considered as an alternative to mono-specific systems as they provide many environmental ecosystem services (da Mota and Schroth, 2014). Cocoa-based agroforestry systems (CAFS) play an important role in biodiversity conservation as well as carbon sequestration (Mbolo *et al.*, 2016). In Indonesia, Clough *et al.* (2011) reported that, CAFS provide habitats for wildlife, while in Cameroon, they serve as reservoirs for seeds from the forest (Sonwa *et al.,* 2017) outside protected areas. Saj *et al.* (2017) reported that, cocoa

agroforestry systems where shade is not removed after cocoa maturity can contribute to a landscape matrix conserving high levels of biodiversity through providing buffer and refuge zones for wildlife. Tropical agroforestry systems has been widely documented for providing a number of ecosystem services that might help sustain the production of multiple crops, improve farmers' livelihoods and conserve biodiversity. Agroforestry systems such as cocoa-based agroforestry are known to contributes to tree resource conservation around protected areas by satisfying farmers' needs in terms of supplying tree resources formerly obtained from the forest and as such reduces their dependence on resources from protected areas (Cheikh and Kowero, 2014; Njongue *et al.,* 2017; Miyuki and Ramni, 2014). Agroforestry maintains local biodiversity out of the protected area therefore, there is need to identify and promote land use strategies that are compatible with the maintenance of local biodiversity. The Dja Biosphere Reserve a biodiversity hotspots, one of the biggest forest reserve in Cameroon and a UNESCO world heritage site since 1987 has as its main objective to conserve biodiversity. Despite the importance of this reserve in conserving biodiversity, it is facing degradation such as encroachment into the reserve for agricultural expansion, hunting of animals and overexploitation of forests resources to meet the demands of the growing population (Oke, 2007; Tabue *et al.* 2018). During these process, many plant and animal species are destroyed and are threatened with extinction which will affect the well-being of the population at long term. In order to overcome the impact of forest encroachment and overexploitation of forest resources, it is necessary to identify options that could provide these products the population needs in order to reduce pressure on tree products from the reserve (Brussaard *et al.,* 2010).Options such as agroforestry systems aim at maintaining these valuable tree species. Therefore this study has as objective to assess the contribution of cocoa-based agroforestry systems in conserving tree species diversity.

2. Materials and methods

2.1 Location of study

The Dja Biosphere Reserve is situated in the southeastern regions between latitudes 2°4430'N - 3°1530'N and Longitudes 12°430'E -

13°3930'E of the Greenwich meridian (Figure 1). The Dja reserve and its peripheral zones is found in the Upper Nyong division which is made up of the North and East clusters and the Dja and Lobo division including the West and South clusters. The climate is of the equatorial type and the monthly average temperature lies between 23.5°C and 24.5°C and the annual rainfall of 1600 mm (Sonke and Couvreur, 2014). Agriculture is the main activity of the population living at the buffer zone and transition zone of the reserve and cultivate crops such as cocoa, coffee, and cassava. This study was conducted in the buffer zone and transition zone of the Dja Biosphere Reserve.

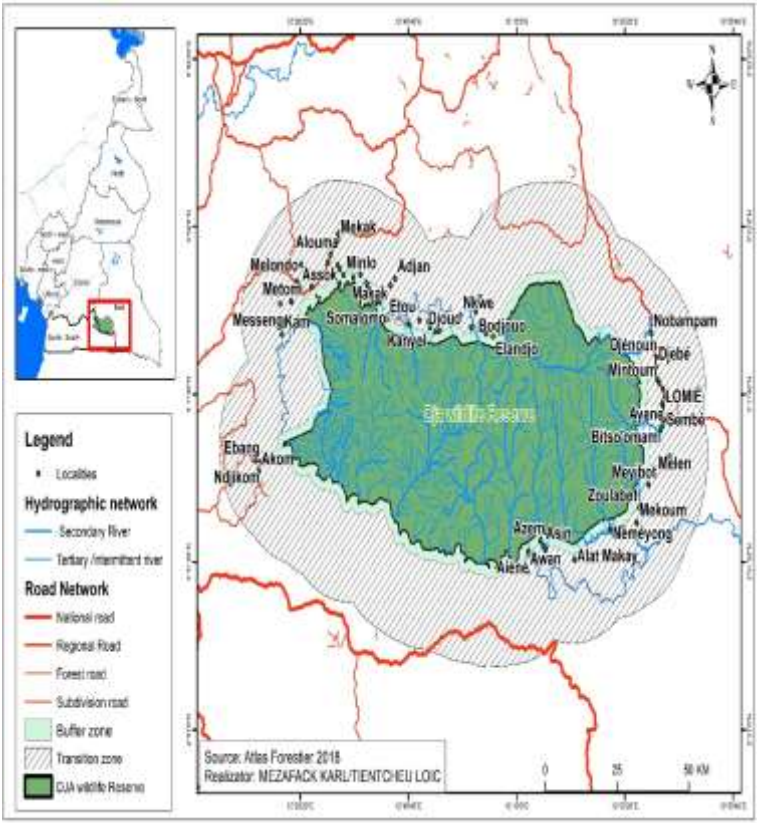


Figure 1: Location of study area

2.2 Data collection

The floristic composition and structure of cocoa agroforestry systems was assess in farmer's fields of the North, South, and East and West clusters of Dja Biosphere Reserve. In each cluster, 25 famers practicing cocoa-based agroforestry were randomly selected based on an interview which was conducted with each farmer to gather information on their cocoa agroforestry system. Some of the aspects covered in the interview included age of the farm, associated trees and their uses and management practices. After the interview, each farmer was requested to lead the research team to his farm for a transect walk and field appraisal .For the vegetation surveys and inventory of tree species reported by the farmer, rectangular plots of 2000 m^2 (100 m × 20 m) were laid in each cocoa-based agroforestry systems following the method described by Hairiah *et al.,* (2010). In each plot, the diameter at breast height (DBH 1.3 m above ground) and height of all stems were measured. Within these plots, subplots of 40 × 5 m^2 (200 m^2) were laid to measure tress with DBH between 5 cm and 30 cm and 10 m × 20 m for plots with irregular shape . On each farm, we count the number of trees, measure the total height and DBH of the cocoa trees, as well as associated trees. In all the plots of the study, the spatial distribution of cocoa trees and associated trees do not follow any particular pattern, nor any arrangement, there were either scattered, dispersed, mixed or dotted. The approximate locations of each sampled plot was assessed using a Garmin GPS (Global Positioning System). The DBH of each tree species was noted and this was used to determine the structure and names of trees species to determine the floristic diversity of cocoa agroforestry systems in the study area. Each tree species was identified using local names and some scientific names were identified by a forester. Twenty five plots were laid per cluster on cocoa farms of different ages (ranging from 5 years to 30 years and above) on a total surface area of 18.02 hectares. The species diversity was assessed using the Shannon index (H). It was calculated following the formula below:

$$H = -\sum_{i=1}^{n} \left(\frac{ni}{N}\right) Log2\left(\frac{ni}{N}\right)$$

ni= number of individuals of species in a given community

N = total number of all species in a given community

Log 2 = logarithm base 2

The structure of CAFS was calculated using density (D) and basal area (BA)

$$D = \frac{\text{Number of individuals}}{\text{Total surface area sampled}} \text{ (Number of individual/ha)}$$

Basal area (BA) = $G = \Pi D^2 / 4$ (m^2)

D = diameter measured at breast height

The importance value index (IVI) of tree species was ranked within a site based on (1) how common the species occur in CAFS expressed as frequency; (2) total number of individuals of the species as expressed density; (3) total basal area occupied by the species expressed as dominance. The IVI was calculated as the relative values of frequency, density and dominance. An IVI of 10 and above was considered as high. The IVI was calculated following the formular below:

IVI = RF (relative frequency) + RD (relative density) + RDo (relative dominance)

$$RF = \frac{\text{Number of occurrence of a species}}{\text{Total occurrence of all species}} \times 100$$

$$RDo = \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$$

$$RD = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

To understand the role of CAFS in the conservation of tree species, we determined the species conservation status of each inventoried species in the systems. Following the IUCN categorization of forest tree species (IUCN 2015), each tree species identified was classified as (i) vulnerable and (ii) near threatened. The biodiversity R of the R

software was used to analyze the data and ANOVA was used to test the significance difference for tree species density and basal area between the four clusters.

3. Result and discussion

3.1 Floristic diversity of CAFS around the Dja Biosphere Reserve.

An abundance of 1582 trees were recorded all the four clusters representing 67 species and 63 genera belonging to 29 families identified on a total surface area of 18. 02 hectares surveyed. The most abundant families were Euphorbiaceae which accounted for 9.5 % of the total individuals surveyed followed by Malvaceae and Mimosaceae representing 7.9 %. Out of the species recorded, fourteen trees species constituted the basic flora of the area because they occurred in all the four clusters which include: *Ceiba pentandra* (2.26 %), *Albizzia glaberrima* (7.01 %), *Allanblackia floridunda* (0.99 %), *Alstonia boonei* (3.26 %), *Baillonella toxisperma* (0.85 %), *Duboscia macrocarpa* (1.06 %), *Ficus mucuso* (5.81 %), *Hevea brasilensis* (1.26 %), *Irvingia gabonensis* (1.20 %), *Musanga cecropioides* (2.69 %), *Pentaclethra macrophylla* (2.33 %), *Petersianthus macrocarpus* (4.53 %), *Ricinodendron heudoletii* (5.74 %) *and Terminalia superba* (6.44 %). The distribution pattern and species composition of cocoa agroforestry systems around the Dja Biosphere Reserve was studied and data pertaining to floristic diversity is presented in Table 1. Species richness varied from 30 in the East cluster to 50 in the west cluster.

Table 1: Diversity indices

Clusters	Abundance	Species richness	Shannon
East	349	30	2.95
North	446	37	3.03
South	378	41	3.00
West	409	50	3.39

Shannon index varied from 2.95 in the East cluster and 3.39 in the West cluster. The clusters (South and West) at the transition zone were

more diverse and had high values of Shannon index than those at the buffer zone (East and North). This could be explained by the fact that cocoa-based agroforestry systems at the buffer zones are closer to the reserve and the farmers obtained most tree-based products from the reserve and turn to conserve less tree species on their farms. Cocoa-based agroforestry systems at the transition zone were more diverse because there are not closer to the reserve where they can extract the products they need therefore, they maintained these valuable tree species on their cocoa farms.

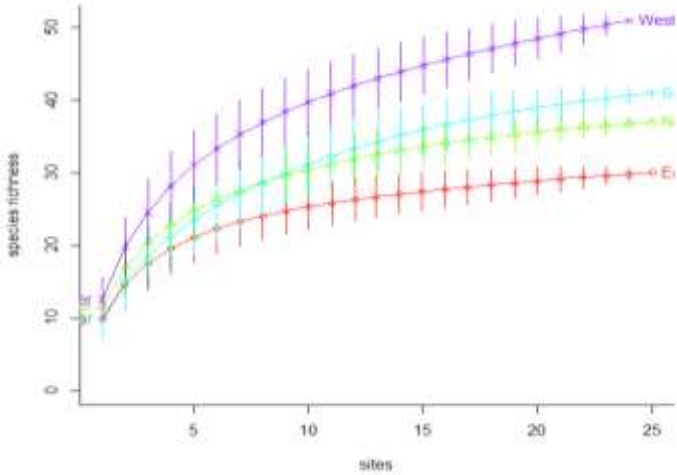


Figure 2: Tree species accumulation curve of cocoa-based agroforestry systems for the four clusters.

The tree species accumulation curve showed that species richness in cocoa-based agroforestry systems varied from 10 to 50 species. The accumulation curves for the four clusters shows that the species are slightly unevenly distributed as the curve rises slowly from 10 species and above.

3.2 Structure of cocoa agroforestry systems around the DBR

The mean basal area varied from 11.72 m^2 in the North cluster to 12.21 m^2 in the South cluster. The mean density was 108 stems/ha in the North cluster and 113 stems/ha in the South cluster (Table 3). ANOVA test indicates significance difference ($p \geq 0.05$) for tree

species density per cluster and Turkey test showed that this significance difference was between the East and North cluster. However, no significance difference was observed for basal area between the four clusters.

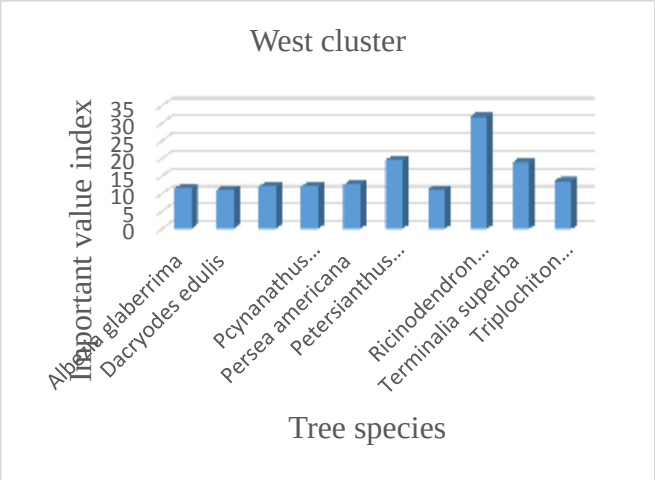
Table 3: Some structure parameters of cocoa agroforestry system per cluster

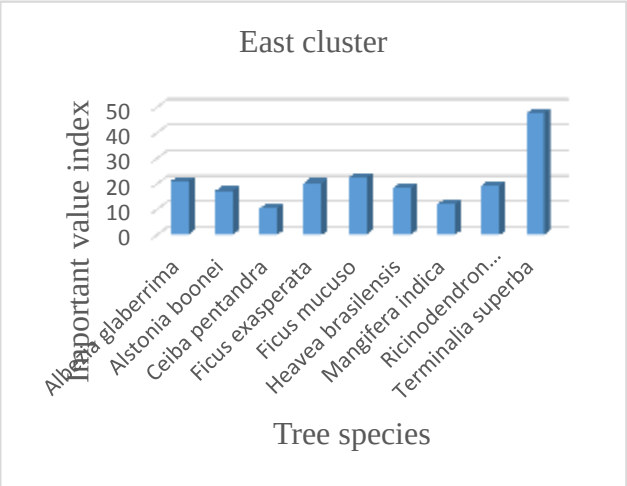
Cluster	Mean basal area (m^2/ha)	Mean density of trees (Stems/ha)	Mean diameter (cm)	Mean height (m)
East Cluster	11,72±9.65 [a]	108±47 [a]	26.04	12.78
North Cluster	12,45±7.38 [a]	140±37 [b]	22.72	8.97
South cluster	11,80±8.45 [a]	117±a27 [ab]	25.67	12.24
West Cluster	12,21±7.37 [a]	113±38 [ab]	27.15	12.47
All	**12,04±8.14**	**120±39**	**25.24**	**11.48**

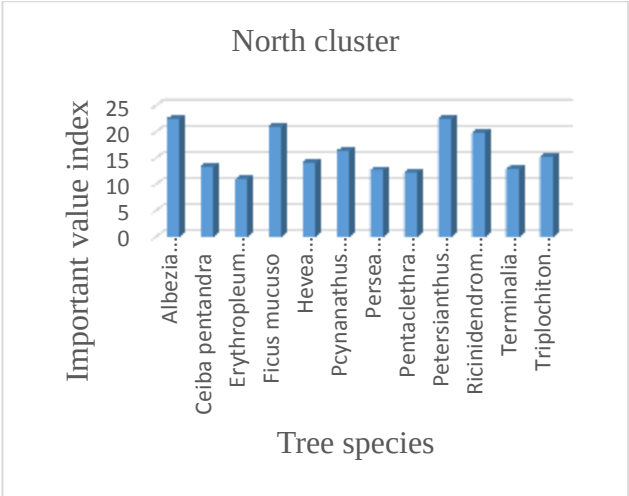
3.3 Important value index of tree species identified around the Dja Biosphere Reserve

The important index value of 10 and above was considered as high. In cocoa-based agroforestry systems around the Dja Biosphere Reserve, nineteen species representing 14.5 % accounted for the overall important value index. In the East cluster, 32.14 % had the highest IVI (28) such as *Terminalia superba* (47.6 %), *Albizzia glaberrima* (20.93 %), *Ficus exasperata* (20.38 %), *Ricinodendron heudelottei* (19.34 %), *Alstonia boonei* (17.16 %), *Mangifera indica* (11.89 %) and *Ceiba pentandra* (10.29 %). The highest IVI was observed for 23.25 % of tree species surveyed in the West cluster such as *Ricinodendron heudelottei* (31.78 %), *Petersianthus macrocarpus* (19.53 %), *Terminalia superba* (18.79 %), *Triplochiton scleroxylon* (13.55 %), *Persea americana* (12.56 %), *Distemonanthus benthamianus* (12.06 %). In the North cluster trees species with the highest IVI index were *Terminalia superba* (22.9 %), *Petersianthus macrocarpus* (22.5 %), *Albizzia*

glaberrima (22.4 %), , *Ricinodendron heudelottei* (19.9 %), %), %), *Ceiba pentandra* (13.4 %), *Terminalia superba* (12.9 %), and *Erythropleum ivorense* (10.9 %) representing 40 % of tree species surveyed. In the South cluster, 26.66 % 0f tree species inventoried had the highest IVI including *Ricinodendron heudelottei* (41.7%), *Terminalia superba* (41.1 %), Alstonia *boonei* (24.28 %), *Perssea americana* (20 %) and *Dacryodes edulis* (11.7 %) (Figure 3). The most important tree species were fruit trees and those that serve as shade trees for the cocoa plants.







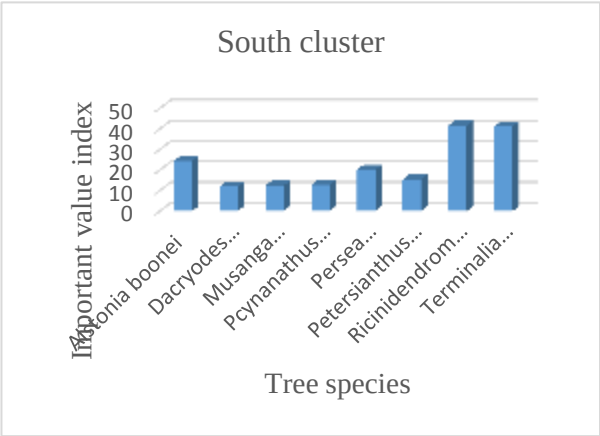


Figure 3: Identified tree species with the highest Important Value Index in cocoa-based agroforestry systems for the four cluster around the Dja Biosphere Reserve

3.4 Conservation status of tree species in cocoa-based agroforestry systems

Some tree species listed on the IUCN as vulnerable and near threatened were recorded in cocoa agroforestry systems around the Dja Biosphere Reserve presented in Table 4 below. These represent 22.85 % of tree

species surveyed in cocoa-based agroforestry systems around the Dja Biosphere Reserve. 10 % of these tree species are vulnerable and 12.85 % of these tree species are near threatened.

Table 4: List of threatened tree species surveyed in cocoa-based agroforestry systems around the Dja Biosphere Reserve

IUCN conservation status of tree species	**Density if individual**	**Proportion (%)**
Vulnerable *Baillonnella toxisperma*	13	0.57
Entandrophragma angolense	8	0.35
Entandrophragma candollei	8	0.35
Entandrophragma cylindricum	1	0.04
Guarea cedrata	3	0.13
Lovoa trichilioides	1	0.44
Pterocarpus soyauxii	10	0.44
Near threatened *Milicia excelsa*	23	1
Triplochiton scleroxylon	25	1.09
Ceiba pentandra	25	1.09
Alstonia boonei	46	2
Cola acuminata		
Erythrophleum ivorense	10	0.44
Desordesia glaucescens	1	0.04
Cylicodiscus gabonensis	4	0.17
Anonidium manii	2	0.09

Discussion.

Floristic diversity of cocoa-based agroforestry systems

A species richness of 30 and 37 were recorded in the East and North clusters found at the buffer zone. The South and West clusters had 41 and 50 species respectively. The species richness obtained in the clusters at the buffer zone was low compared to clusters at the periphery (South and West). This could be explained by the fact that farmers at the buffer zone obtained most of their products from the reserve and do not bother retaining many species on their farms. Those at the transition zone due to long distances to the reserve turned to maintain and plant diverse trees on their farms. The results of this inventory were similar to 38 species in traditional CAFS in Central Cameroon (Madountsap *et al.,* 2019), 40 species identified in three CAFS types (traditional, innovative and SODECAO) in the locality of Talba (Center Region of Cameroon) by Ngono *et al.* (2015) but higher than 26 species identified by Manfo *et al.* (2015) in the same Region and 21 species identified by Madountsap *et al.* (2017) in SODECAO CAS in the locality of Talba. However, this diversity remains low compared to 59, 70 and 61 species recorded respectively by Jiofack *et al.* (2013), Jagoret *et al.* (2014) and Mapongmetsem *et al.* (2016) in complex CAS in the same Region of Cameroon, 62 species in Cocoa Agroforests of Southern Cameroon by Zapfack *et al.* (2016). This differences in species obtained could be explained by the fact that farmers in localities such as Talba established cocoa agroforestry systems following recommendations by SODECAO for cocoa cultivation. Around the Dja Biosphere Reserve, cocoa farmers create complex cocoa-based agroforestry systems in which they conserve more tree species. The could be explained by the fact that they faced difficulties in felling these trees, interests in multipurpose uses of these tree species which they turned to maintain on their farms and the inadequate technical knowledge to established cocoa-based agroforestry system.

The Shannon index in cocoa-based agroforestry systems around the Dja Biosphere Reserve varied from 2.95 to 3.43, similar to reports by Zapfack *et al.* (2016) in the CAF of South Cameroon (3.66), but higher than results obtained by Jagoret *et al.* (2014), 2.42 for the Shannon index in CAFS of Bokito, Zima and Ngomedzap (Cameroon), those of Asase and Tetteh (2010) in Ghana (2.6) and Salgado-Mora *et al.* (2007)

in Mexico (2.9). The high values of Shannon in CAFS around the Dja Biosphere Reserve could be due to the fact that, these systems are found in a tropical area and close to forests where more diversified tree species are maintained on farms. Low Shannon index are observed mostly in savanna zones where few tree species are found on farmers' farms.

Structure of cocoa-based agroforestry systems

The mean basal area showed no significance difference between the four clusters. However a significance difference ($p \leq 0.05$) was observed for tree density between the East and West clusters. This could be explained by differences in mean height between the North and East clusters because the density of a tree affects tree height. This is in lined with report by Zeide and Curtis (2002) who found out that density helps to explain variation in height that is, height increases monotonically with tree species density Tree species such as *Petersianthus macrocarpus, Albizzia glaberrima, Ricinodendron heudelottii, Ceiba pentandra, Terminalia superba, and, Alstonia boonei* had high importance index values mainly due to high species richness, abundance, and basal area of the constituent species. The IVI is commonly used in ecological studies as it shows ecological importance of a species in a given community. The IVI is also used for prioritizing species conservation whereby species with low IVI requires high conservation priority compared to the tree species with high IVI as reported by (Kacholi, 2014).

Conservation status of tree species in CAFS

In the Dja Biosphere Reserve, a number of woody tree species are maintain in cocoa agroforestry systems which contribute to biodiversity conservation. This study highlights the role of cocoa agroforestry systems to support tree species richness and provides evidence of farmers' farms as biodiversity reservoirs. Woody species present on the farmlands are mostly local multipurpose species that farmers protect or grow on their farms. As reported by Vodouhe *et al.* (2011), agroforestry parkland systems as well as other traditional agroforestry practices support biodiversity through in situ conservation of tree species on farms. The choice of integrated tree species in the farming systems is guided by many reasons peculiar to farmers such as contribution to household nutrition and health care. Local people make deliberate

efforts to plant these tree species on their farmlands. This is a local strategy to support biodiversity conservation in the area and reinforces the importance of the role played by these useful species in the livelihoods of the local communities.

Conclusion

The objective of this study was to investigate the role of cocoa-based agroforestry systems in conserving tree species diversity. The floristic diversity was high for the four clusters and clusters at the transition zone were more diversified than clusters at the buffer zone. Tree species which provided fruits and served as shade trees for cocoa plants were highly valued in all the clusters and farmers maintained or plants these tree species on their cocoa farms. The results revealed that 22.85 % of forest tree species were surveyed in cocoa-based agroforestry systems around the Dja Biosphere Reserve. This result revealed the contribution of cocoa-based agroforestry systems in conserving vulnerable and threatened tree species of the Dja Biosphere reserve. Therefore, cocoa agroforestry systems around protected areas could serve as reservoirs for biodiversity conservation if managed effectively. Cocoa-based agroforestry systems are highly valued by farmers due to the growing markets for cocoa beans and diverse tree products farmers obtained from these systems which served as food and they also sell to generate income. This study clearly revealed that the maintenance of high tree species diversity in cocoa-based agroforestry systems around the Dja Biosphere Reserve will served as an important safety net for the local population.

References

Asase Alex and Tetteh Daniel (2010). *The role of complex agroforestry systems in the conservation of forest tree diversity and structure in southeastern Ghana.* Agroforestry Systems, 79, 355–368.

Brussaard Lijbert, Caron Patrick, Campbell Bruce, Mirjam Pulleman (2010). *Reconciling biodiversity and food security: Scientific challenges for a new agriculture.* Current opinion in environmental sustainability, vol 2, 1-2.

Cheikh Mbow and Kowero Godwin (2014). *Agroforestry solutions to address food security and climate change in Africa*. Environmental sustainability, vol 6, p 61 – 67.

Clough Yann, Barkmann Jan, Juhrbandt Jana, Kessler Micheal, Wanger TC, Anshary A, Buchori D, Cicuzza D, Darras K, Putra D, Erasmi S, Pitopang R, Schmidt C, Schulze CH, Seidel D, SteffanDewenter I, Stenchly K, Vidal S, Weist M, Wielgoss AC, Tscharntke Teja (2011). *Combining high biodiversity with high yields in tropical agroforests*. Proceedings National Academic Science USA. 108: 8311 – 8316.

Hairiah Kurniatun, Dewi Soyan, Agus Fahmuddin, Velarde Sandra, Ekadinata Andree, Rahayu Subekti, van Noordwijk Meine (2010). *Measuring carbon stocks across land use systems*: A manual. Bogor, Indonesia. World Agroforestry Centre (ICRAF), SEA Regional Office. 155p.

Jagoret Patrick, Kwesseu Jacques, Messie C, Dounias MI, Male ZE (2014). *Farmers' assessment of the use value of agrobiodiversity in complex cocoa agroforestry systems in central Cameroon*. Agroforestry Systems, 88, 983–1000. doi:10.1007/s10457-014-9698-1

Jiofack T, Guedje NM, Tchoundjeu Z, Fokunang C, Lejoly J, Kemeuze V (2013). *Agroforestry typology of some cocoa based agroforests in the Mbam and Inoubou division: the importance for local population livelihoods*. J Ecol Nat Environ 5:378–386. doi:10.5897/JENE12.085.

Kacholi David (2014). *Analysis of structure and diversity of the Kilengwe forest in the Morogoro region, Tanzania*. International journal of biodiversity, 4: 1-8. http:/dx.org/10, 1155, 516840.

Madountsap Tagnang Nadège*, Zapfack Louis, Chimi Djomo Cédric, Kabelong Banoho Louis-Paul, Tsopmejio Temfack Ingrid, Forbi Preasious Funwi, Ntonmen Yonkeu Amandine Flore, Nasang Julliete Mancho (2019).*Carbon storage potential of cacao agroforestry systems of different age and management intensity*, Climate and Development, 11:7, 543-554, DOI: 10.1080/17565529.2018.1456895

Madountsap Tagnang Nadège, Zapfack Louis, Chimi Djomo Cédric, Kabelong Banoho Louis-Paul, Tsopmejio Temfack Ingrid, Forbi Preasious Funwi, Ntonmen Yonkeu Amandine Flore, Nasang Julliete Mancho (2017). *Biodiversity and carbon stock in the SODECAO agroforestry system of center region of Cameroon: Case of talba locality* American Journal of Agriculture and Forestry, 5(4), 121–129.

Manfo Donald, Tchindjang Mesmin, Youta Happi (2015). *Systèmes agroforestiers et conservatio de la biodiversité dans un milieu fortement anthropisé : le cas d'Obala*. Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo, 5, 22–34.

Mapongmetsem PM, Etchiké D, Ngassoum MB (2016*). Conservation et valorisation de la biodiversité dans les agroforêts de la zone périurbaine de la ville Bafia (Région du Centre au Cameroun).* Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo, 6, 60–69.

Mbolo Marguerite Marie Abada, Jules Christian Zekeng, William Armand Mala, Jean Louis Fobane, Cedric Djomo Chimi (2016). *The role of cocoa agroforestry systems in conserving forest tree diversity in the Central region of Cameroon*. Agroforestry Systems, 90:577-590 DOI 10.1007/s10457-016-9945-8.

Miyuki Liyama and Ramni Jamnadas (2014). *The potential of agroforestry in the provision of sustainable wood fuel in sub Saharan Africa*. Environmental sustainability, vol 16, pg 138 – 147.

Da Mota Maria and Schroth Gotz (2014). *Agroforestry: Complex multistrata agriculture*. Encyclopedia of agriculture and food systems, 2nd edition, Elsevier Editors.

Ngono F, Mala AW, Levang P, Ambang Z (2015*). Evolution des systèmes agroforestiers cacao et impact environnemental à Mbangassina: cas du village Talba*. Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo, 5, 62–67.

Njongue Njongue, Avana Tientcheu Marie-Louise, Éric Fotsing, Muderhwa Patrick (2017). *Assessing farmers' interest in Agroforestry practices around the Mount Cameroon National Park (MCNP) in Cameroon.* International Journal of Geomatics, Planning and Resources Management. Vol 2. N°e_ISSN: 2520 – 9574.

Oke D. O, Odebiyi K. A (2007) *Traditional cocoa-based agroforestry and forest species conservation in Ondo State, Nigeria*. Agric Ecosyst Environ 122:305–311

Saj Stephane, Torquebiau Emmanuel, Hainzelin Etienne, Pages J (2017). *The way forward: An agro-ecological perspective for climate-smart agriculture*. Agriculture Ecosystems and Environment. 250: 20-24

Salgado-Mora MG, Ibarra-Nu´n˜ez G, Marcı ´as-Sa´mano JE, Lo´pez-Ba´ez O (2007). *Diversidad arborea en cacaotales del Soconusco*, Chiapas, Mexico. Interciencia 32:763–76

Sonké Bonaventure and Couvreur Thomas (2014*). Tree diversity of the Dja Faunal Reserve, southeastern Cameroon*. Biodiversity Data Journal 2: e1049. doi: 10.3897/BDJ.2.e1049.

Sonwa Denis, Weise Stephan, Nkongmeneck Bernard, Tchatat M, Janssens Marc (2017). *Structure and composition of cocoa agroforests in the humid forest zone of southern Cameroon*. Agroforestry Systems, 91,451–470.

Tabue Bruno, Louis Zapfack, Valery Noiha, Forbi Funwi, Jules Zenkeng, Louis RN, Louis RK, Nadège MT, Amandine FN, Mireil CT, Nyeck B, Cedric Chimi (2018). *Diversity, structure and carbon storage potential of the Dja Reserve vegetation cover*. Journal of Biodiversity and Environmental Sciences. Vol. 13, No. 5, p. 180-199.

Vodouhe Fifanou, Coulibaly Ousmane, Biaou Gauthier, Sinsin Brice (2011). *Traditional agroforestry systems and biodiversity conservation in Benin (West Africa*) Agroforest Syst, 82:1–13

Zapfack Louis, Chimi Djimi, Noiha Valery, Zekeng Jules, Meyan-ya, Tabue Mbobda (2016). *Correlation between Associated Trees, Cocoa Trees and Carbon Stocks Potential in Cocoa Agroforests of Southern Cameroon*. Sustainability in Environment, Vol. 1, No. 2, ISSN 2470-637X (Print) ISSN 2470-6388.

Zeide Boris and Curtis Vanderschaaf (2002). *The effect of density on the height-diameter relationship*. Forest service, southern research station, p 463-466