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# Cocoa-based agroforestry systems and its potential for tree resource conservation around the Dja Biosphere Reserve Southeastern Cameroon

**Njini Loveline Munjeb[1*], Marie-Louise Avana Tientcheu[1], Yerima Bernard Kfuban Palmer[2] and Roger Kogge Enang[2]**

[1]Department of Forestry, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon.
[2]Department of Soil Sciences, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon.

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**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 East of Cameroon. This reserve is divided into four clusters due to its large nature and location between two regions. A random sampling approach was adopted, whereby, 100 plots of 100 m × 20 m and 10 m × 20 m were laid down in cocoa-based agroforestry systems on a total surface area of 18.02 ha. 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 as, tree 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 the study area, belonging to 69 species, 63 genera and 28 families. Species richness was lowest in the east cluster (30) and highest in the west cluster (50). Shannon diversity index varied from (2.95) for the east cluster to (3.39) for the west cluster. Mean basal area varied from 11.72 $m^2$ for the North cluster to 12.21 $m^2$ for the South cluster. Mean density varied from 108 stems/ha for the North cluster to 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%). The ANOVA test indicates a significant difference ($p \leq 0.05$) for tree density between clusters, while Turkey test shows that this significant difference was between the East and North clusters. However, no significant difference was observed for basal area between the four clusters. Thirty percent of tree species found in cocoa-based agroforestry systems were listed on the IUCN red list of plants species, indicating the contribution of these systems in conserving threatened tree species. The study concluded that cocoa agroforestry systems around protected areas can serve as reservoirs for biodiversity conservation if managed effectively.**

**Key words:** Tree, species, conservation, diversity, cocoa, agroforestry, system.

## INTRODUCTION

Tropical agroforestry systems have been widely documented for providing a number of products and services that improve farmers' livelihoods and conserve biodiversity (Harvey et al., 2006; Jose, 2009). These agroforestry systems can be defined as a form of multiple cropping under which three fundamental conditions are met: (i) at least two plant species interact biologically; (ii) at least one of these two species is a woody perennial

and (iii) at least one of them is managed for forage, annual or perennial crop production (Deheuvels, 2011; Somarriba et al., 2013; da Mota and Schroth, 2014; Van Noordwijk et al., 2016). Shaded tree-crop systems (involving crops such as coffee (*Coffea* spp.) and cocoa (*Theobroma cacao* L.)) are prominent examples of agroforestry systems (Somarriba et al., 2012). Three million smallholder farmers cultivate 7-8 million ha of cocoa (*T. cacao* L.) worldwide (www.worldcocoafoundation.org), with at least 80% of the cocoa cultivated in agroforestry systems that is, together with diverse tree species and other useful plants on the same plot (Deheuvels, 2011; Sombarriba et al., 2013). The ecological and socio-economic importance of cocoa-based agroforestry systems is acknowledged worldwide (Somarriba et al., 2013; Mbolo et al., 2016; Madountsap et al., 2020). Cocoa-based agroforestry systems play an important role in biodiversity conservation, carbon sequestration, soil fertility and climate change (Anglaaere et al., 2011; Gockowski and Sonwa, 2011; Gockowski et al., 2010; Nair, 2012; Awazi et al., 2019; Azembouh et al., 2021), while supplying tree resources formerly obtained from the forest around protected areas (Cheikh and Kowero, 2014; Miyuki and Ramni, 2014; Njongue et al., 2017; Somarriba, 2018). Moreover, cocoa-based agroforestry systems are drought resistant and serve as weed and pest biological control (Tscharntke et al., 2011) and they can mimic the structural and functional elements of the forest (Gockowski et al., 2005). In Costa Rica, Deheuvels et al. (2014) showed that shade tree crops such as cocoa provide habitats for numerous forest dependent species of high conservation value. In Indonesia, Clough et al. (2011) revealed that cocoa-based agroforestry systems provide habitats for wildlife. In Cameroon, they serve as reservoirs for plant from the forest (Leakey and Tchoundjeu, 2001; Sonwa et al., 2001) outside protected areas. The Dja Biosphere Reserve is one of the biggest forest reserve in Cameroon and a UNESCO world heritage site since 1987. Its main objective is 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 and overexploitation of forests resources to meet the demands of the growing population (Oke and Odebiyi, 2007; Tabue et al., 2018). During these processes, many individual species are destroyed and are facing a high risk of extinction in the wild. In order to overcome the impact of forest encroachment and overexploitation of forest resources, it is necessary to identify options that can 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 can achieve this goal as they maintain some of these valuable tree species. Therefore, this study has as objective to assess the contribution of cocoa-based agroforestry systems in conserving tree species diversity. Specifically to assess the floristic diversity and vegetation structure of cocoa-based agroforestry systems in the buffer and transition zones around the Dja Biosphere Reserve. This is to determine the conservation value of these cocoa-based agroforestry systems around the Dja Biosphere Reserve.

## MATERIALS AND METHODS

### Location of study

The Dja Biosphere Reserve is located between latitude 2°310'-3°5220'N of the equator and longitude 12°2020'-13°5040'E (Figure 1). The climate is of the equatorial type and the monthly average temperature lies between 23.5 and 24.5°C and the annual rainfall of 1600 mm (Sonké and Couvreur, 2014). The Dja Reserve, its buffer and transition zones are 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 reserve is divided into four clusters due to its large area and location between two regions of Cameroon. Two clusters found at the buffer zone (North and East) and two at the transition zone (South and West). The study was conducted in all the four clusters to compare cocoa-based agroforestry systems at the buffer and transition zones and their ability to offer habitats for tree species of the reserve. Agriculture is the main activity of the population living at the buffer zone and transition zone of the reserve and they cultivate crops such as cocoa, coffee, and cassava.

### Data collection

The floristic composition and structure of cocoa-based agroforestry systems were assessed in farmer's fields of the North, South, East and West clusters of the Dja Biosphere Reserve. In each cluster, 25 farmers practicing cocoa-based agroforestry systems were randomly selected based on an interview, which was conducted with each farmer to gather information on their cocoa-based agroforestry system. A total of 100 plots were sampled in cocoa-based agroforestry systems. 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. Elongated rectangular plots were laid in each cocoa-based agroforestry system following the method described by Hairiah et al. (2010). The area and shape of each cocoa-based agroforestry system were previously mapped using a GPS track function and ranged from 0.4 to 6.02 ha, with a high variability of shapes. The center of the plots was determined and it was used to establish permanent plots of 100 m × 20 m (2000 $m^2$) sampling units.

The orientation and location of each sampling unit was based on the size and shaped of the plot.

*Corresponding author. E-mail: njini.loveline@yahoo.com.

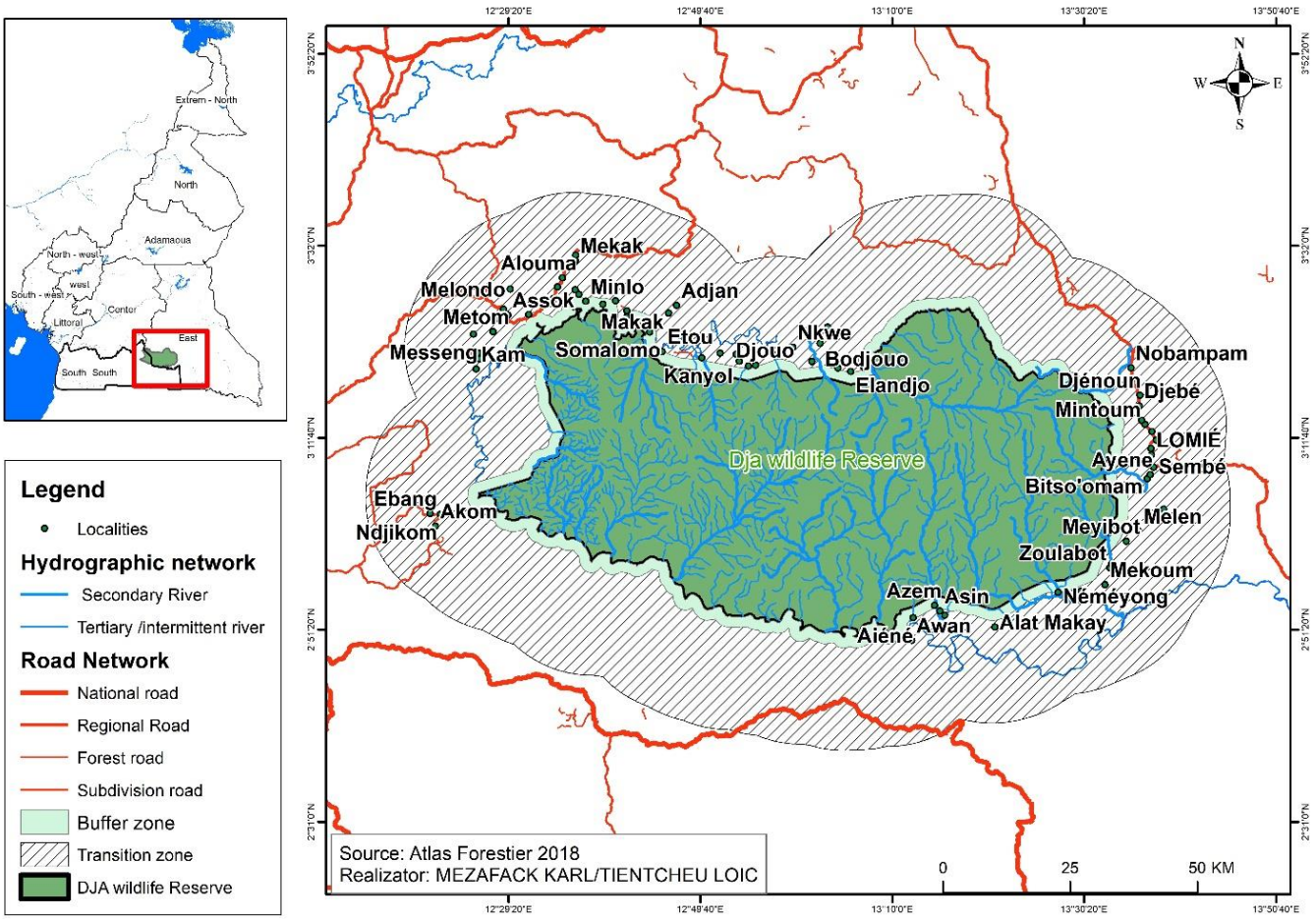


**Figure 1.** Location of study area.

The vegetation structure of cocoa- based agroforestry systems were characterized into two vertical stratum: (1) the cocoa tree understory layer where cocoa trees and associated trees were counted, their diameter at breast height was measured with a measuring tape and their maximum height was noted. (2) The canopy stratum. The diameter at breast height was measured at 1.3 m from the ground with a measuring tape. The height of the trees was measured which was used to estimate the basal area of trees in cocoa-based agroforestry systems in the study area. Each tree species was identified using local names and scientific names were identified by a forester and a botanist. Twenty five plots were laid per cluster on cocoa farms of different ages (ranging from 5 to 30 years and above) on a total surface area of 18.02 ha. The species diversity was assessed using the Shannon index (H) (Maguran, 2004). It was calculated following the formula:

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

where ni = number of individuals of species in a given community, N = total number of individuals of species in a given community, and Log 2 = natural logarithm.

The structure of cocoa-based agroforestry system was calculated using tree density (D) and basal area (BA) as shown:

$G = \pi d^2/4$

where D = diameter measured at breast height and G = basal area of trees ($m^2$/ha).

The importance value index (IVI) of tree species was ranked based on (1) how common the species occur in cocoa-based agroforestry systems, expressed as frequency in samples; (2) total number of individuals of the species; (3) total basal area occupied by the species. An IVI greater than or equal to 10 was considered as high and below 10 was considered low (Kacholi, 2014). The IVI was calculated following the formula below:

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

RF = Number of occurrence of a species / Total occurrence of all species × 100

RDo = Total basal area of a species / Total basal area of all species × 100

RD = Number of individuals of a species / Total number of individuals of all species × 100

To understand the role of cocoa-based agroforestry systems 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) endangered

**Table 1.** Diversity indices.

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

(EN), (ii) vulnerable (VU), and (iii) near threatened (NT).

**Data analysis**

The Biodiversity R package (Kindt and Coe, 2005) of the R software program (R Core Team, 2014) was used for data analyss. Species richness and diversity indices were computed. Species area curves showing the cumulative increase of species in number with increasing cocoa-based agroforestry system was drawn. Shannon indices were used to compare species diversity per cluster. An ANOVA test was used to test significant difference ($p \leq 0.05$) for basal area and tree density per cluster.

## RESULTS

### Floristic diversity of cocoa-based agroforestry systems around the Dja Biosphere Reserve

A total abundance of 1582 trees were recorded belonging to 63 genera and 69 species. Out of the 1582 trees (DBH ≥ 5 cm) that were measured, 741 (46.83%) were native trees and 841 (53.16%) were fruit trees. The trees recorded belong to 28 botanical families. The most abundant families were Euphorbiaceae which made up 9.5% of the total individuals studied followed by Malvaceae and Mimosaceae (7.9% each), and Annonaceae, Fabaceae and Caesalpiniaceae (6.3% each). Families such as Myristicaceae, Stericulaceae, Lauraceae, and Combretaceae which had only one species constituted 1.5% each. The frequency of occurrence of tree species varied between clusters. Fourteen trees species constituted the basic flora of the area as they occurred in all the four clusters. They 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%) of total individuals. Species richness was the lowest in the East cluster (30) and highest in the West cluster (50) Table 1.

Shannon varies from 2.95 in the East cluster to 3.39 in the West cluster (Table 1). The South and West clusters, with more diverse species had the highest values of Shannon index than the North and East clusters (Table 1). 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 as 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.

The tree species accumulation curve showed that species richness in cocoa-based agroforestry systems varied from 10 to 50 species (Figure 2).

The accumulation curves for the four clusters show that the species are slightly unevenly distributed as the curve rises slowly from 10 species and above.

### Structure of cocoa agroforestry systems around the Dja Biosphere Reserve`

The diameter of trees measured ranged from 5 to 175 cm. The majority of trees measured had diameters up to 60 cm and few native trees had diameters greater than 175 cm (Figure 3).

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 2). The ANOVA test indicates a significant difference ($p \leq 0.05$) for tree species density per cluster, while the Turkey test showed that this significant difference was between the East and North clusters. However, no significant difference was observed for basal area between the four clusters.

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

In the East cluster, *T. superba* (47.6%), *A. glaberrima* (20.93%), *Ficus exasperata* (20.38%), *R. heudelottei* (19.34%), *A. boonei* (17.16%), *Mangifera indica* (11.89%) and *C. pentandra* (10.29%) had the highest IVI. The highest IVI of tree species surveyed in the West cluster included *R. heudelottei* (31.78%), *P. macrocarpus* (19.53%), *T. superba* (18.79%), *Triplochiton scleroxylon* (13.55%), *Persea americana* (12.56%), and

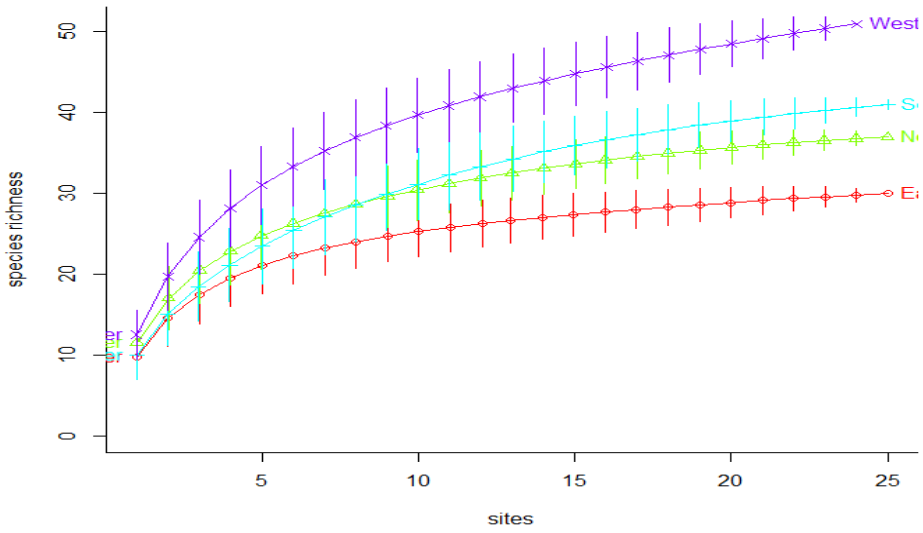


**Figure 2.** Species accumulation curve of cocoa-based agroforestry systems for the four clusters.

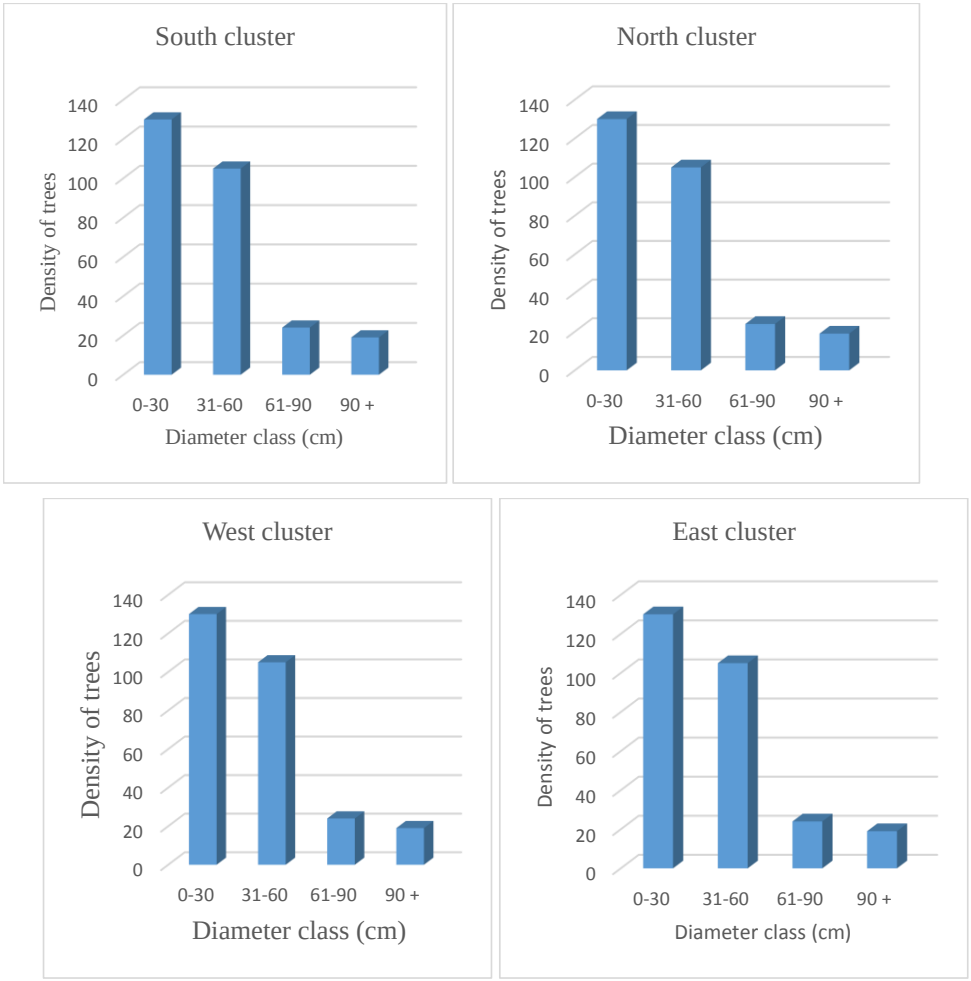


**Figure 3.** Diameter classes of trees measured in cocoa-based agroforestry systems for the four clusters around the Dja Biosphere Reserve.

**Table 2.** Some structure parameters of cocoa agroforestry system per cluster.

| Cluster | Mean basal area (m²/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 |

*Distemonanthus benthamianus* (12.06%). In the North cluster trees species with the highest IVI index were *T. superba* (22.9%), *P. macrocarpus* (22.5%), *A. glaberrima* (22.4%), *R. heudelottei* (19.9%), *C. pentandra* (13.4%), *T. superba* (12.9%), and *Erythropleum ivorense* (10.9%). In the South cluster, tree species with the highest IVI included *R. heudelottei* (41.7%), *T. superba* (41.1%), *A. boonei* (24.28%), *Perssea americana* (20%) and *Dacryodes edulis* (11.7%) (Figure 4). The most important tree species were fruit trees and those that serve as shade trees for the cocoa plants reported by farmers.

### 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-based agroforestry systems around the Dja Biosphere Reserve (Table 3). These represent 22.85% of tree species surveyed in cocoa-based agroforestry systems around the Dja Biosphere Reserve. Ten percent of these tree species were vulnerable, while 12.85% of them are near threatened.

## DISCUSSION

### Floristic diversity of cocoa-based agroforestry systems

A species richness of 30 and 37 were recorded in the East and North clusters, respectively 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 obtain most of their products from the reserve and do not bother retaining many species on their farms. Increasing tree density at the buffer zone will reduce farmers' dependence on resources from the reserve. Those at the transition zone due to long distances to the reserve tend to maintain and plant diverse trees on their farms. The results of this inventory are similar to those of 38 species in traditional CAFS in Central Cameroon (Madountsap et al., 2019) and those of 40 species identified in three CAFS (traditional, innovative and SODECAO) in the locality of Talba (Center Region of Cameroon) by Ngono et al. (2015). They are however, higher than those of 26 species identified by Manfo et al. (2015) in the same region and those of 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, and those of 62 species in Cocoa Agroforests of Southern Cameroon by Zapfack et al. (2016). The 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. Moreover, farmers faced difficulties in felling these trees, are interested in the multipurpose uses of these tree species, which they tend to maintain on their farms, and the inadequate technical knowledge to establish cocoa-based agroforestry systems.

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). They were higher than results obtained by Jagoret et al. (2014), 2.42 for the Shannon index in CAFS of Bokito, Zima and Ngomedzap (Cameroon), and those of Asase and Teteh (2010) in Ghana (2.6) and Salgado-Mora et al. (2007) in Mexico (2.9). The high values of Shannon could be due to the fact that, cocoa-based agroforestry systems are found in tropical areas close to forests where more diversified tree species are maintained on farms. Low Shannon indices are observed mostly in savanna zones where few tree species are found on farmers' farms.

### Structure of cocoa-based agroforestry systems

Larger diameter of trees above 100 cm in these cocoa farms can be attributed to management practices on the cocoa farms which begin with selective cutting of trees leaving desired tree species to provide shade for the cocoa farms, fruits, timber and medicines. The small

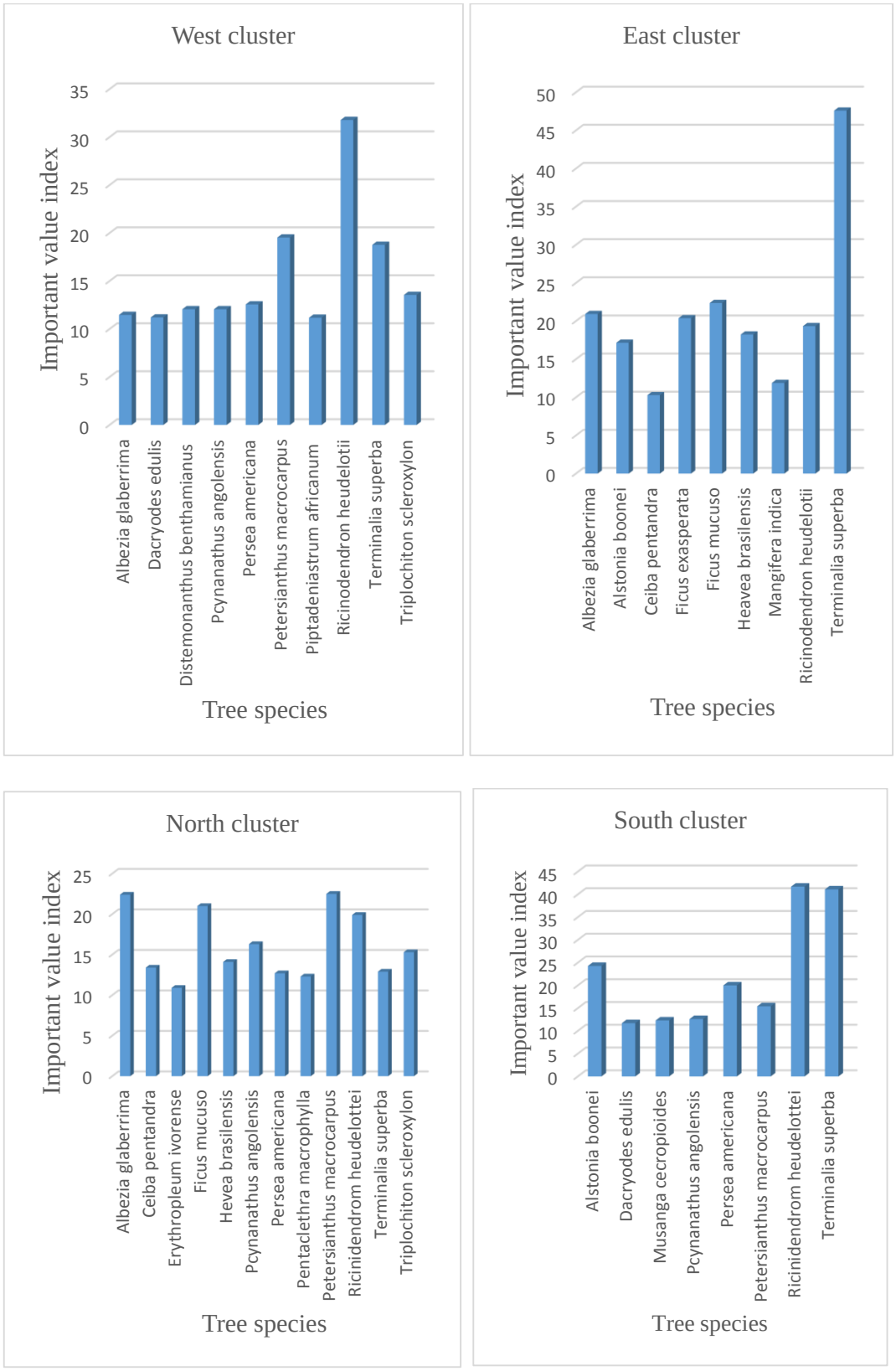


**Figure 4.** Important Value Index of tree species in cocoa-based agroforestry systems for the four cluster around the Dja Biosphere Reserve.

**Table 3**. List of threatened tree species surveyed in cocoa-based agroforestry systems around the Dja Biosphere Reserve.

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

diameter (< 60 cm) of most trees suggests they are young, probably planted in the course of the agroforestry system establishment. The mean basal area showed no significant difference between the four clusters. However, a significant difference ($p \leq 0.05$) was observed for tree density between the East and West clusters. Tree species such as *P. macrocarpus, A. glaberrima, R. heudelottii, C. pentandra, T. superba, P. macrocarpus* and *A. boonei* had high important value index mainly due to their high species richness, abundance, and basal area of the constituent species. These tree species were maintained or planted on farmers' farms motivated by their diverse uses indicated by farmers. The IVI is commonly used in ecological studies as it shows ecological importance of a species in a given ecosystem. The IVI is also used for prioritizing species conservation whereby species with low IVI value need high conservation priority compared to the ones with high IVI (Kacholi, 2014). The low IVI in some cases can be due to the species being naturally rare or have been intensively exploited.

## Conservation status of trees in cocoa-based agroforestry systems

In the Dja Biosphere Reserve, a number of woody tree species are maintained 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 farms as biodiversity reservoirs. Woody species present on the farmlands are multipurpose tree species that farmers protect or grow in their fields. 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 strategy to support biodiversity conservation in the area and reinforces the importance of the role played by these useful species in the livelihood of the local community.

## 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 planted these trees on their cocoa farms. The results revealed that 22.85% of the forest tree species were surveyed in cocoa-based agroforestry systems around the Dja Biosphere Reserve. These results showed 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. 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 are also sold to generate income. This study indicates that the maintenance of high tree species diversity in cocoa-based agroforestry systems around the Dja Biosphere Reserve will serve as an important safety net for the local population.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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