What Does the Status of Forest Conservation Reveal about Biodiversity of Tropical Forest?

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ABSTRACT

Objective: Ecological monitoring and sustainable management of forest ecosystems require deep knowledge and understanding of biodiversity. Notwithstanding this, useful data are still limited in most of the tropical regions. This study assessed the status of biodiversity in sacred and classified forests in northwestern Benin. **Methodology and results:** Woody plants were inventoried in 2 sacred and 3 classified forests within plot sizes of 50 × 30 m. Relative frequencies and Pearson *Chi-square* independence tests were performed to identify the top 20 and 10 families and species, respectively. Biodiversity indicators such as Shannon's entropy, species richness and Gini-Simpson index were assessed as well.

Conclusions and application of findings: In the present study, we reported 76 species belonging to 58 genera and 27 families. The most abundant families were Fabaceae, Sapotaceae, Combretaceae, Meliaceae, Anacardiaceae and Rubiaceae. We also found a strong association of species families with forest types. Shannon's entropy values and Gini-Simpson indices differed significantly among forests. The diversity indices values were higher in classified forests than in sacred ones. Both classified and sacred forest shelter mostly species interesting for populations and researchers. All the inventoried species are in the threatened species category on the IUCN red list, with 3 vulnerable species (*Khaya senengalensis*, *Vitellaria paradoxa* and *Afzelia africana*) and 2 endangered ones (*Pterocarpus erinaceus* and *Garcinia* sp). These results revealed the relevance of local strategies to protect natural resources and the need of additional strategic actions for sustainable biodiversity conservation and management of these forests under anthropogenic pressures.

Keywords: Biodiversity; Forests; Conservation; Sustainability; Benin

INTRODUCTION

Forest ecosystems provide population with essential goods and services, and constitute a source of financial income. In Africa, around 600 million people depend on forest resources. Several raw materials from forests are commonly used by 80% of African population for health purposes. In addition, these ecosystems are of great importance in achieving sustainable development objectives, particularly those addressing poverty, food security, climate change, and desertification and biodiversity conservation issues [1].

Forests are suffering from human activities, which derived from land usage and agricultural practices. The impact of human activities and other anthropogenic pressures are well documented. In fact, human actions have resulted in reducing of forests coverage as well as biodiversity, and unbalanced plant communities. The report published by the ''Banque Mondiale'', indicated that forests of Benin have declined from 7.6 million to 5.9 million hectares from 2005 to 2015. Then, these losses represent 14% of the total forest areas of Benin in 2005. Therefore, it is an urgent need to take some actions to preserve plant diversity among forests.

The implementation of actions and policies to sustain forests preservation requires deep knowledge and understandings of biodiversity they gathered. Most of the challenges in assessing the diversity within forests rely on their types and complexities. Since then, great attention is being paid to diversity indices such as Shannon's entropy and Simpson's index in determining the abundance and diversity of species. Several studies have documented the conservation status of biodiversity among forests across Africa. However, these studies lacked of advanced analyses tools including Shannon's entropy and the Gini-Simpson index, and were limited to species richness index. Besides, they did not investigate the difference in biodiversity indicators among the conservation status of diverse forests such as sacred, community and classified forests. For example, Kouadio, et al. assessed the biodiversity among the dense forest of the dodo Voluntary Nature Reserve (NVR) in the southwest of Cote d'Ivoire using Shannon's entropy as an indicator. Accordingly, they inventoried 242 species with the Shannon's diversity indices of 3.008, 2.578, 3.506, and 2.455 in dense forest, secondary forest, fallow and savannah included respectively. Besides, Kitoko, et al. has recently pointed out higher species richness among sacred forest in the Kongo central province in the democratic republic of Congo. However, Ricotta pointed out the importance of improving these indices upon the study of species with special status.

In Sub-Saharan Africa, the ecological monitoring and sustainable management of forests are quite challenging as scientific data on the status of their biodiversity are lacking. These informations are of interest and require much attention than anthropogenic. In the present study, we assessed the status of biodiversity within sacred and classified forests under anthropogenic threats at Djougou district in Northwestern Benin [2-5].

MATERIALS AND METHODS

Study site

This study was conducted at Djougou district in 5 forests including 3 classified and 2 sacred. This district is located in the Sudano-Guinean transition zone (7°30'N and 9°45"N), in the Bassila phytodistrict which is characterized by a sub-humid tropical climate with annual rainfall varying between 1200 mm and 1300 mm, and humidity index ranging from 2.7 to 3.9. The soils in this phytodistrict are tropical ferruginous types with deep waterlogging. The climax vegetation is dense forest semi-deciduous dominated by *Khaya grandifoliola* and *Aubrevillea kerstingii*. The genus *Aubrevillea* is endemic to this phytodistrict which species richness is estimated at 450 plant species with Leguminosae (15%), Rubiaceae (11%) and Euphorbiaceae (4%) as the more an abundant families [6].

Sampling and data collection

The methodology used for data collection was adapted from Salako, et al. Plants species were inventoried within plot sizes of 30 m × 50 m randomly set in each forests. The number of plots set per forest is summarized in Table 1.

Table 1: Number of plots set per forest.

Forest	Name	Number of plots set
Classified	Belefougoun	38
	Kilir	11
	Serou	22
Sacred	Djadjangou	18
	Yarakeou	12

Note: The conservation status of each species inventoried was thereafter determined from the IUCN red list (Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN)).

Statistical analyses

To describe the taxonomic diversity of the identified species, the number of families and genus were counted. The relative frequencies of occurrence were calculated to highlight the most represented families, as well as the top 20 species found in overall, and 10 per forest type. Pearson's *chi-square* independence test was performed on the n × p matrix (n refers to the top 10 species set in row, and p refers to type of forest set in column) to demonstrate the relationship between these two variables. The same analysis was carried out to measure the association of forest types with conservation status by referring to the IUCN (International Union for Conservation of Nature) red list. The biodiversity appreciation indices including species richness (total number of species), Shanon's entropy (equation 1) and the Gini-Simpson diversity index were calculated using the functions Chao Richness, Chao Shannon and Chao Simpson of the iNEXT package [8-12].

$$H_b(X) = -\sum_{i=1}^{n} P_i \log_b P_i$$

$$D = ((\sum n(n-1))/N(N-1))$$

Where N is the total number of all species, and n is the total number of a specific species.

Statistical analyses were performed using the R statistical software (Version 4.0.0, R foundation for statistical computing, Vienna, Austria) [13-15].

RESULTS

Taxonomic diversity and variation of species among forest types

The inventory results pointed out 73 species belonging to 58 genera and 29 families. The Pearson's *chi-square* test indicated a strong association of species families with forest types (X^2=207.87, df=11, p<0.001). As indicated in Figure 1, the top 20 first families of species inventoried in both classified and sacred forests were mostly dominated by Fabaceae (RFC=28.49%) followed by Sapotaceae (RFC=11.36%), Combretaceae (RFC=9.13%), Meliaceae (RFC=7.83%), Anacardiaceae (RFC=6.03%) and Rubiaceae (RFC=5.82%) [16-18].

However, the families of Mimosoideae and Chrysobalanaceae were only found in sacred forests while that of Celtidacaea was reported from classified forests (Figure 2).
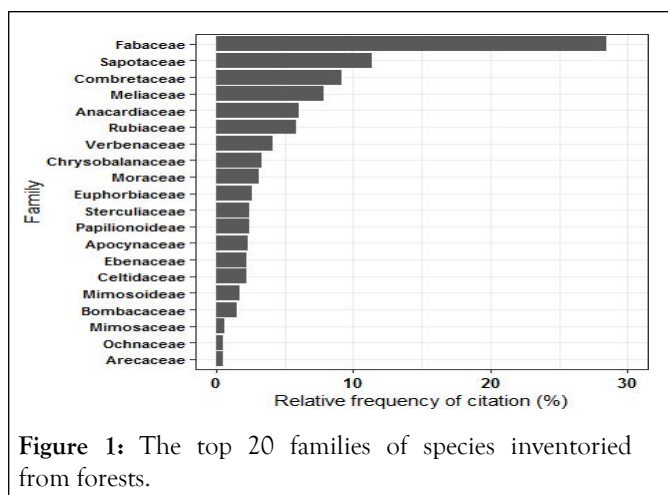

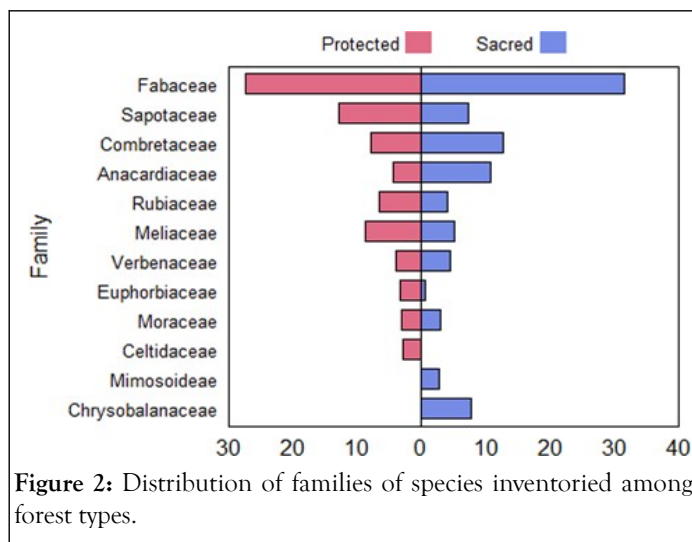**Figure 1:** The top 20 families of species inventoried from forests.

Figure 2: Distribution of families of species inventoried among forest types.

The top 20 first species inventoried among the forests were in overall dominated by *Vitellaria paradoxa* (8.75%), *Isoberlinia doka* (7.55%), *Burkea africana* (5.87%), *Isoberlinia tomentosa* (4.18), and *Isoberlinia tomentosa* (4.18%) followed by *Terminalia leiocarpa* (3.97%), *Khaya senengalensis* (3.86%), *Azadirachta indica indica* (3.53%) and *Canthium hispidum* (3.37%) (Figure 3). Besides, the Pearson's *chi-square* test also indicated a strong association of the top 10 species to forest types (X^2=435.07, df=14, p<0.001).

However, *Azadirachta indica* (4.77%), *Terminalia leiocarpa* (4.63%), *Canthium hispidum* (4.55%), *Malacantha alnifolia* (3.52%) and *Hymenocardia acida* (3.38%) were mainly reported from classified forests while *Lannea acida* (5.44%), *Crossopteryx febrifuga* (3.56%), *Combretum collimum* (5.44%), *Maranthes polyandra* (7.74%) and *Terminalia laxiflora* (3.98%) were found in sacred forests (Figure 4) [19,20].
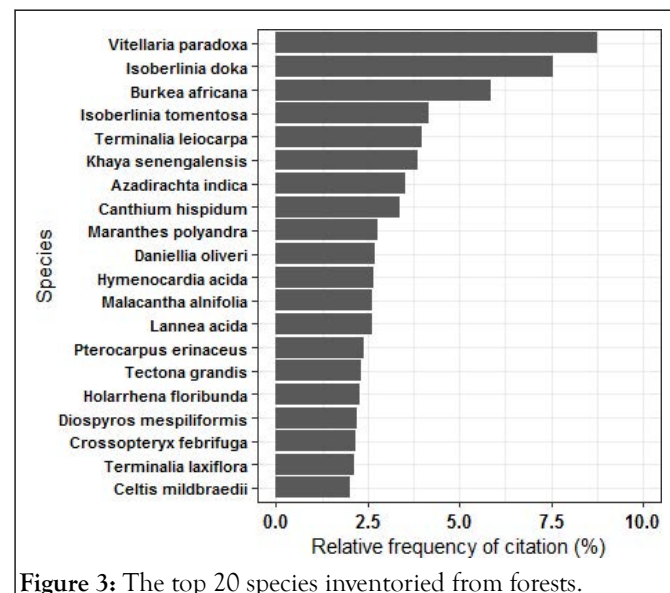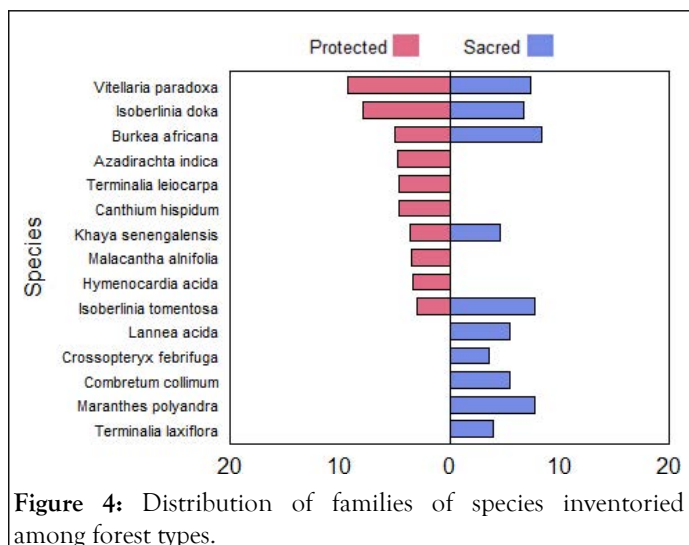

Figure 3: The top 20 species inventoried from forests.

Figure 4: Distribution of families of species inventoried among forest types.

The results indicated that Shannon's entropy values differed significantly among of forest types (confidence interval values of 3.687 and 3.762 *vs.* 3.394 and 3.537 in classified and sacred forests, respectively at 95%) with the high value recorded in classified forests. Similarly, the estimated Gini-Simpson index value was higher in classified forests than in sacred ones (Table 2). However, even though the species richness value recorded in classified forest was higher than that of sacred forest, they were not significantly different [21,22].

The species accumulation curve also indicated that species richness increased along with increase in sample size (Figure 5).

Table 2: Indicators of biodiversity appreciation among forests.

Estimated parameter	Forest	Observed value	Mean ± SE	(95% CL[d]
Shannon entropy	Classified	3.687	3.714 ± 0.024	3.687–3.762
	Sacred	3.394	3.458 ± 0.041	3.394–3.537
	Overall	3.776	3.802 ± 0.802	3.776–3.851
Species richness	Classified	69	73.497 ± 4.799	69.814–93.839
	Sacred	52	56.491 ± 3.962	53.015–71.866
	Overall	79	92.493 ± 12.453	81.897–141.847
Gini-Simpson index	Classified	0.964	0.965 ± 0.002	0.964–0.968
	Sacred	0.955	0.957 ± 0.003	0.955–0.962
	Overall	0.967	0.968 ± 0.001	0.967–0.970

Note: [d]**Confidence limits:** The estimated parameter values were considered to be significantly different if the 95% confidence limits did not overlap.

Figure 5: Evolution of species richness according to sample size among forests.
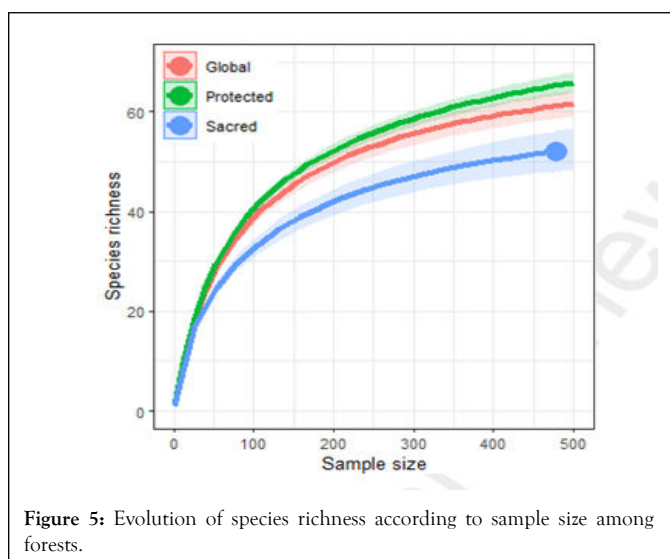
Conservation status of forests

Most of the inventoried species belong to the least concern class (83.97%) followed by vulnerable (13.21%), Endangered (2.39) and near threatened (0.43) classes. *Khaya senengalensis* (Miliaceae), *Vitellaria paradoxa* (Sapotaceae), *Afzelia africana* (Fabaceae) were identified as vulnerable species in both forests of Djougou district by referring to IUCN red list [23-25]. However, *Pterocarpus erinaceus* (Papilionoideae) is the only endangered species recorded in both type of forests while *Garcinia* sp. (Clusiaceae) was only endangered species reported from sacred forests (Table 3).

Table 3: Species status among forests according to IUCN red list.

Forest	Species	Family	Genus	IUCN Statut[1]
Classified	*Khaya senengalensis*	Meliaceae	*Khaya*	VU
	Pterocarpus erinaceus	Papilionoideae	*Pterocarpus*	EN
	Vitellaria paradoxa	Sapotaceae	*Vitellaria*	VU
	Afzelia africana	Fabaceae	*Afzelia*	VU
Sacred	*Khaya senengalensis*	Meliaceae	*Khaya*	VU
	Pterocarpus erinaceus	Papilionoideae	*Pterocarpus*	EN
	Vitellaria paradoxa	Sapotaceae	*Vitellaria*	VU
	Afzelia africana	Fabaceae	*Afzelia*	VU
	Garcinia sp.	Clusiaceae	*Garcinia*	EN

Note: [1]Vulnerable (VU); Endangered (EN)

DISCUSSION

Taxonomic diversity and variation of species among forests

In the present study, the top 20 families of species inventoried in both forests were mainly Fabaceae, Sapotaceae, Combretaceae, Meliaceae, Anacardiaceae and Rubiaceae. These results corroborate with those of Neuenschwander, et al. which reported that the richest species in the flora of Benin belonged to Fabaceae family. Similarly, this family was the most representative in the Badenou classified forest in Ivory coast and in the Djoumouna forest in the republic of Congo. In overall, Fabaceae family is still the most common in tropical forests. Our results also reported numerous subfamilies including Caesalpinioideae, Mimisoideae and Papilionoideae, which enhanced the importance of Fabacea family. However, the abundance of Rubiaceae recorded from the different forests suggests that they did not yet reached climax status [26-30].

In fact, the taxonomic diversity reported in this study (73 species, 58 genera and 29 families) was much lower than that obtained by Gnahore, et al. in the periphery of the Banco National Park in Côte-d'Ivoire, and Miabangana in the Djoumouna forest in the Republic of Congo. This variation may be explained by the differences in ecological zones, the surface of sampled areas, the sampling methods and the number of sampling methods. According to Vroh, et al. the combination of several sampling methods provides a very important floristic richness.

The results pointed out *Vitellaria paradoxa, Isoberlinia doka, Burkea africana, Isoberlinia tomentosa, Isoberlinia tomentosa, Terminalia leiocarpa, Khaya senengalensis, Azadirachta indica* and *Canthium hispidum* as the most dominant species in the forests of Djougou district. These results are not uncommon and have been reported by Adomou characterizing the study area by open forests and wooded savannas with Isoberlinia doka and *Vitellaria paradoxa*. Our results indicated that Shannon's entropy values and Gini-Simpson indices differed significantly among forests. The values of these parameters were higher in classified forests suggesting a lower anthropization in these forests compared to sacred ones. In this study, the Shannon's entropy values obtained from both types of forests are in overall higher than those obtained by Kouadio, et al. However, the low species richness recorded from sacred forests differed from that reported in previous studies. These results may be attributed to the difference in vegetation structure and composition. For example, the sacred forests of Djougou, in Northwestern Benin are rich and more diversified in species than the sacred Badja forest in southwestern Benin [31-33]. This difference may result from the protection effort and the density of the population living alongside the sacred forest of Badja in southwestern Benin.

Conservation status of forests

Knowledge of special status species (threatened species and endemic species) is essential in determining the biodiversity status of specific area. These species are indicators for assessing the priority and the conservation status of forest. Our results showed that all inventoried species are listed in the IUCN red list. Accordingly, we found 3 vulnerable species (*Khaya senegalensis, Vitellaria paradoxa* and *Afzelia africana*) and 2 endangered species (*Pterocarpus erinaceus* and *Garcinia* sp.). Gnahore, et al. have pointed out that these species were all present in sacred forests and were the most vulnerable to anthropogenic pressures. However, the sacred forests of Djougou hosted *Garcinia* sp. which belongs to the Clusiaceae family. As a result, they were considered as high conservation values of category 1, 3 and 6. Therefore, policy documents for better conservation and sustainable management of these forests are needed.

CONCLUSION

In the present study, we assessed the biodiversity status in sacred and classified forests at Djougou district in Northwestern Benin. The results reported 76 species belonging to 58 genera and 27 families. The most abundant families were Fabaceae, Sapotaceae, Combretaceae, Meliaceae, Anacardiaceae and Rubiaceae. We also found a strong association of species families with forest types. Shannon's entropy values and Gini-Simpson indices differed significantly among forests. The diversity indices values were higher in classified forests than in sacred ones. All the inventoried species are in the threatened species category on the IUCN Red List, with 3 vulnerable species and 2 endangered ones. The forests of Djougou can be classified as high conservation values of category 1, 3 and 6. Therefore, strategic actions for sustainable conservation and management of these forests under anthropogenic pressures are needed.

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REFERENCES

1. Adomou AC. The main environmental factors in Benin: Phytogeographic zones of Benin. In: Sinsin B and Kampmann D (eds), Biodiversity Atlas of West Africa, Benin. Cotonou and Frankfurt/Main. 2010;1.

2. Akakpo Ab, Padonou Ea, Assogbadjo Ae, Glele-Kakaki Rl. Assessment of the current state and the main threats to the sacred Badja forest in southwestern Benin: Proposal of conservation strategies. Annals of the University of Parakou-Natural Sciences and Agronomy Series. 2019;9(1):95-106.

3. Badou RB, Yedomonhan H, Tossou M. Diversity of uses and conservation status of *Syzygium guineense* (Willd.) DC. subsp. macrocarpum (Engl.) F. White (Myrtaceae) in Benin. Int J Environ Stud. 2019;76(5):827-842.

4. World Bank. Country note on the forests of Benin. World bank publications, The world bank group, 1818 H Street NW, Washington, DC 20433, USA, 2020;77.

5. Ceperley N, Montagnini F, Natta A. Significance of sacred sites for riparian forest conservation in Central Benin. Woods and Forests of the Tropics. 2010;303(1):5-23.

6. Chao A, Gotelli NJ, Hsieh TC, Sander EL, Ma KH, Colwell RK, et al. Rarefaction and extrapolation with Hill numbers: A framework for sampling and estimation in species diversity studies. Ecol Monogr. 2014;84(1):45-67.

7. Dainou K, Dubart N, Bracke C, Doucet JL. Assessment of the presence of High Conservation Values (HCVs) in concessions managed by Societe Pallisco, Cameroon: Identification, potential threats and management measures for HCVs. University of Liege. 2017;43.

8. Dike IP, Obembe OO, Adebiyi FE. Ethnobotanical survey for potential anti-malarial plants in south-western Nigeria. J Ethnopharmacol. 2012;144(3):618-626.

9. Dossa AKB, Gouwakinnou NG, Sourou BN, Houetchegnon T, Wedjangnon AA, Odjrado KB, et al. Structural characterization of populations of *Detarium senegalense* JF Gmel. (Caesalpiniaceae) following the different formations of the species in Benin, West Africa. J Life Earth Sci. 2019;7(1).

10. FAO. State of the world's forests. Forests and agriculture: Challenges and opportunities for utilisation des terres, Rome. 2016;138.

11. Gboze AE, Sanogo A, Amani BHK, Kassi NJ. Floristic diversity and conservation value Badenou classified forest (Korhogo, Ivory Coast). African Agronomy. 2020;32(1):51-73.

12. Gnahore E, Kone M, Soro Y, N'guessan YJ, Bakayoko A. Effects of anthropization on floristic diversity on the outskirts of Banco national park, Abidjan, Cote d'Ivoire. Africa Science. 2020;16(4): 167-180.

13. Guillaume A. The main environmental factors in Benin: Soils of Benin and vegetation cover. In: Sinsin B and Kampmann D (eds), Biodiversity Atlas of West Africa, Benin. Cotonou and Frankfurt/Main. 2010.

14. Ismael M, Kouta S, Sogbossi E, Imorou IT. Effect of anthropogenic factors on the woody Biomass of the goungoun classified forest and its bordering lands in the soudianne Region of Benin. Int J Progress Sci Technol. 2020;22(2):304-318.

15. Kagambega FW, Zampaligre N, Zida D, Sawadogo L. Impact of human activities on the woody diversity and structure of *Vitellaria paradoxa* Gaertn. C.F. in the Shipyard. 2019.

16. Koffi CK, Djoudi H, Gautier D. Landscape diversity and associated coping strategies during food shortage periods: Evidence from the Sudano-Sahelian region of Burkina Faso. Reg Environ Change. 2017;17:1369-1380.

17. Kombate B, Dourma M, Folega F, Woegan AY, Wala K, Akpagana K. Floristic diversity and structural characterization of wooded formations in the Sudano-Guinean domain in central Togo. S Afr. 2020;17(6):29-43.

18. Kouadio YJC, Soiret KSP, Kpan WB, Yao NO, N'guessan KE, Kouassi KP, et al. Conservation value of the dodo Voluntary Nature Reserve (RNV), South-West Coast d'Ivoire (West Africa). Int J Biol Chem Science. 2018;12(6):2784-2796.

19. Larrieu L, Gonin P. LIndice de Biodiversite Potentielle (IBP) to assess the potential biodiversity of forest stands. In: XIII world forestry congress. Forests in development, a vital balance. 2009.

20. Miabangana ES. Floristic structure, composition and diversity of the Djoumouna forest (Republic of the Congo). Eur Sci J. 2020;16(12): 179-203.

21. Missa K, Ouattara DN, Kone M, Bakayoko A. Floristic study and diversity of the Marsh forest Tanoe-Ehy (South East of Cote d'Ivoire). J Anim Plant Sci. 2015;25(3):3917-3938.

22. Momo Solefack MC, Temgoua LF, Fongnzossie Fedoung E, Zangmene Djouda R. Vegetation and functional spectra of the gallery forest of Koupa Matapit (West-Cameroon). Geo-Eco Too. 2018;42(1):147-158.

23. Neuenschwander P, Sinsin B, Goergen G. Nature conservation in West Africa: A red list for Benin. Nature conservation in West Africa: Red list for Benin. International institute of tropical agriculture, Ibadan, Nigeria. 2011;365.

24. Nsielolo Kitoko R, Kiyulu N'yanga Nzo BJ, Ndungu Mukwela R. Floristic inventory of the sacred forest of Wuya in the province of Kongo central in the Democratic Republic of Congo. Afr Sc. 2020;16(1):218-225.

25. Obossou FK, Adjakpa JB, Dansi MF, Dissou FE, Azonningbo SHW, Yedomonhan H. 2020. Floristic and structural study of the Ahouanhouzoukan Community Forest in Tevedji in the Commune of Ouinhi in southern Benin Rev. Ivory Sci Technol. 35:288-308.

26. WHO. WHO strategy for traditional medicine. World health organisation. 2002;1-65.

27. R Development Core Team. 2016. A: A language and environment for statistical computing. R foundation for statistical computing: Vienna, Austria.

28. Ricotta C. Bridging the gap between ecological diversity indices and measures of biodiversity with Shannon's entropy: Comment to Izsak and Papp. Ecol Modell. 2002;152:1-3.

29. Salako VK, Houehanou TH, Assogbadjo AE, Akoegninou A, Kakai RL. Patterns of elephant utilization of *Borassus aethiopum* Mart. and its stand structure in the Pendjari National Park, Benin, West Africa. Trop Ecol. 2017;58(2):425-437.

30. Toyi MS, Eda F, Barima YS, Bamba I, Sinsin B. Landscape dynamics of the lama classified forest in southern Benin. Tropicultura. 2018;36(2):217-231.

31. Traore L, Sambare O, Savadogo S, Ouedraogo A, Thiombiano A. Combined effects of anthropogenic and climatic factors on the population status of three vulnerable woody species. Int D Biol Path Sci. 2020;14(5):1763-1785.

32. Tuo FN, Koffi KJ, Kouassi AF, Kone M, Adama B, Bogaert J. Study of the diversity, endemism and spatial distribution of Rubiaceae in Côte d'Ivoire. Int J Biol Chem Sci. 2017;11(2): 777-797.

33. Vroh BTA, Adou YCY, Kouame D, N'da DH, N'guessan KE. Floristic and structural diversity on the site of a voluntary nature reserve in Azaguie, South-East Côte d'Ivoire. Eur J Sci Res. 2010;45(3):411-421.