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Assessment of the biodiversity of sacred forests in the Atlantic department in Southern Benin

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Abstract

In Benin, the sacred forests constitute vestiges of heavily anthropized primary forests. In order to assess the importance of plant biodiversity in the sacred forests of the Atlantic department in South Benin, a forest inventory was carried out in five islands of sacred forests (Hêkpazoun : 25 ha ; Avogbézoun, Sindomè, Ahouansêzoun et Assanmeyzoun : 10 ha each). Structural parameters were compared between forests with analysis of variance tests. The results obtained show that the specific richness of the woody plants varies from 6 species (sacred forest of Hêkpazoun) to 20 species (sacred forest of Avogbézoun) with good distribution of trees between the different species regardless of the sacred forest considered (diversity index of Shannon varying between 3.17 and 4.11). Regarding the dendrometric parameters, only the mean diameter varied significantly (Prob. <0.05) from one sacred forest to another. The largest trees were observed in the sacred forests of Avogbézoun (60.75 cm) and Ahouansêzoun (58.96 cm) while the smaller trees were observed in the sacred forests of Assanmeyzoun (32.03 cm) and Sindomè (42.50 cm). *C. mildbraedii, F. thonningii, T. prieurianna*, *D. guineense*, *V. doniana* and *T. scleroxylon* were the main characteristic species of sacred forests. Although the structural features do not indicate an alarming degradation of these ecosystems, measures must be taken for their conservation.

Keywords: Sacred forests; Forest inventory; Specific richness; Dendrometric parameters; Benin

1. Introduction

Unlike the countries of the Gulf of Guinea, Benin has only 2,664,075 ha of classified domains established since the 1930s. In addition to this classified domain, there are the sacred forests and other "deified" formations sheltering the tutelary deities and the secret societies. According to Sokpon et al. (1998), there is at least one sacred forest in each Municipality of Benin. There are generally links between the sacred forest and the history of the village to which it belongs. It is even common for some villages to bear the same names as the sacred forests they shelter. But, despite the considerable areas they represent as a whole, these forests are rarely taken into account in the official national statistics of forest formations in Benin. However, these plant formations play a considerable socio-cultural and ecological role. They are sometimes home to water sources on which villages depend in all seasons and enjoy privileged status with traditional

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societies. Also, through their relationship with nature, they contribute significantly to the protection of natural resources.

These sacred forests are undergoing severe degradation today. The driving forces behind their degradation are, among others, demographic pressure, the erosion of traditional religious beliefs and the current weakness of the power of religious leaders, increased land pressure (Kokou et al., 2005). This pressure has resulted in the fragmentation of forest ecosystems, particularly in southern Benin. The result was relics of forests dominated by a few large scattered trees, vestiges of natural formations. To assess the woody potential of sacred forests, Agbo and Sokpon (1998) identified 2,940 sacred forests in the country, the total area of which was estimated at nearly 18,360 hectares, or about 0.2% of the total area of the forest country. From this inventory, it emerged that small sacred forests (area up to 1 ha) represented almost 70% of the total number. On the other hand, forests with an area of between 1 and 5 ha, covered 18% of the total. There are other large sacred forests such as Igbo doléo (1,600 ha), Adjougni (1,200 ha), Ekpasso (800 ha), Igbo Lakou (600 ha), Félia (600 ha) in the department of Zou, as well as Adakplamé (450 ha) in the Department of Ouémé.

Kokou and Kokutse (2006) established a typology of these sacred plant formations. According to their function, these sacred forests were grouped into fetish forests (59.6%), secret society forests (20.8%), community forests (9.8%) and cemetery forests (8.33%). To document the value of sacred forests and their biological diversity, numerous studies have been carried out (Sokpon and Agbo, 1999; Kokou and Sokpon, 2006; Kokou et al, 1999a; 1999b). But most of these only covered areas of southern Benin (up to the level of the 7th parallel). However, despite the flurry of these studies, it is easy to observe that very little work has focused exclusively on the sacred forests of the Department of the Atlantic, an area of southern Benin yet renowned for its richness in sacred forests. In the era of decentralization, taking into account this ecological heritage could help strengthen the economy of the ecological potential of this Department. Also, the present study aims to analyze the current structural characteristics of the sacred forests of the Atlantic Department and to provide elements allowing to judge the value of these sacred forests in terms of biodiversity and heritage wealth.

1.1. Study environment

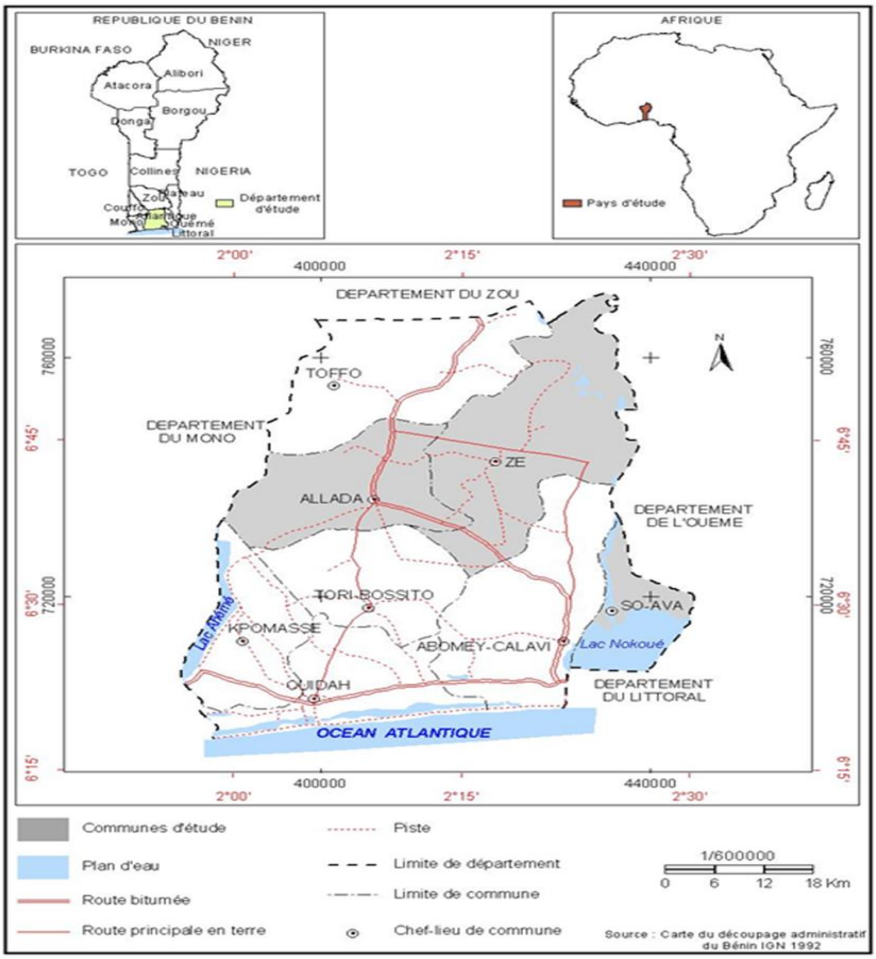

Figure 1 Category of study setting

The choice of the Atlantic department as the study area is justified in particular by the fact that this department has one of the highest densities in Benin (250 inhabitants / km2: INSAE, 2013). This situation predisposes it to a strong anthropization of the landscape detrimental to the conservation of natural resources. In addition, this department is strongly influenced by the "voodoo" cult which gives the forests studied their sacredness. The average annual rainfall is 1200 mm in the area. The climate there is of the subequatorial type with two dry seasons: a large rainy season ranging from April to July, a small dry season in August, a small rainy season ranging from September to November, and finally a large dry season ranging from from December to March. The average annual temperature is 29.9 °C with the hottest months of the year being February, March and April while July, August and September are the coolest. The soils of this department are dominated by red-colored sandy clay soils called bar land. In the Lama depression, black vertisols are found with a high clay content. The plant cover is strongly marked by the human footprint. Only a few patches of forest relics of the primary dense forests which covered a large part of the southern part of the country are observed there. Five classified forests (Lama, Djigbé, Tozoun, Ouèdo and Pahou) are counted in the department. In addition, many artificial plantations resulting from various national reforestation programs and private agricultural promotion are installed in the department.

2. Material and methods

2.1. Sampling and data collection

The study covered five of the sacred forests of the Atlantic Department (Hêkpazoun: 25 ha; Avogbézoun, Sindomè, Ahouansêzoun and Assanmeyzoun: 10 ha each). They were selected from the directory of sacred forests established by Sokpon and Agbo (1999). The systematic sampling method was used for the installation of plots. Each of the forests selected for the study was crisscrossed with a grid of 20 x 20 m square plots. Quantitative data was collected through ecological surveys. Specimens of species that could not be identified in the field were collected and then identified by the National Herbarium of Benin. To assess the interest of the sacred forest for the populations, a summary survey was carried out using a semi-structured questionnaire among the populations living near these classified forests. To this end, twelve people were selected around each classified forest, a total of 60 people were surveyed. The information collected concerned

- The origin of the sacred nature of the forest,
- The relationships that the populations have with the forest,
- The access rules and prohibitions and (iv) the activities carried out in the forest.

2.2. Statistical data processing and analysis

To assess the structural characteristics of sacred forests, two types of ecological parameters were considered. Ecological diversity parameters included species richness and Shannon diversity index (see Gillet, 2000 for formulas) while dendrometric parameters included tree density (N, trees / ha), mean tree diameter (Dm, cm), the basal area of trees (G, m2 / ha), bole (Hf, m) and total heights (Ht, m) (see Rondeux, 1999; Kangas and Maltamo, 2007 for the formulas). Dendrometric parameters were compared between classified forests using one-way analyzes of variance (Crawley, 2013) (sacred forest). The conditions for applying the analysis of variance (normality and equality of population variances: Glèlèkakaï et al., 2006) were checked beforehand. Concerning the characteristic species of each classified forest, they were determined from the indices of values of ecological importance (see Curtis and Macintosh, 1951 for the formulas). Statistical analyzes were performed with R software version 3.4.1 (R Core Team, 2017).

3. Results

3.1. Structural features of sacred forests

The phytocenosis of sacred forests is a true witness to the primary forest of the Department in terms of plant composition. The highest specific resources are observed in the classified forests of Assanmeyzoun (20 species) and Hêkpazoun (17 species) while the lowest specific resources are observed in the classified forests of Sindomè (6 species) and Avogbézoun (8 species). The high values observed for the Shannon diversity index, regardless of the sacred forest considered, indicates a good distribution of trees among the different species (Table 1).

Table 1 Trees distributions among the different species

Sacred forests	Specific wealth	Shannon Diversity
Sindomè	6	3.58
Avogbézoun	8	3.17
Ahouansêzoun	13	3.43
Hêkpazoun	17	3.74
Assanmeyzoun	20	4.11

The results of the dendrometric characteristics are presented in Table 2. Analysis of this table reveals that only the mean diameter of the trees varied significantly (Prob. <0.05) from one sacred forest to another. Analysis of average characteristics shows that the largest trees were observed in the sacred forests of Avogbézoun (60.75 cm) and Ahouansêzoun (58.96 cm) while the smaller trees were observed in the sacred forests of Assanmeyzoun. (32.03 cm) and Sindomè (42.50 cm). Although not statistically different (Prob. <0.05), the highest basal areas were observed in the sacred forests of Hêkpazoun (G = 4.70 m2 / ha) and Ahouansêzoun (G = 4.75 m2 / ha) while the lowest basal area was observed in the sacred forest of Assanmeyzoun (3.77 m2 / ha). Regarding bole heights and total tree heights, the highest values were observed in the sacred forests of Sindomè (Hf = 7.67 m and Ht = 11.75 m), Assanmeyzoun (Hf = 7.18 m) and Avogbézoun (Ht = 12.00 m) while the highest values were observed in the sacred forest of Ahouansêzoun (Hf = 5.88 m and Ht = 9.29 m).

Table 2 Dendrometric parameters of sacred forests: mean (Avg), coefficient of variation (Cv) and probability value (Prob.)

SacredForests	Statistics	Dendrometric parameters			
		G (m^2/ha)	Dm (cm)	Hf (m)	Ht (m)
Avogbézoun	Moy	4.67	60.75	7.00	12.00
	Cv (%)	67.16	39.90	24.45	17.54
Sindomè	Moy	4.26	42.50	7.67	11.75
	Cv (%)	112.62	75.28	40.13	27.41
Ahouansêzoun	Moy	4.75	58.96	5.88	9.29
	Cv (%)	93.60	51.35	50.06	32.36
Hêkpazoun	Moy	4.70	53.09	6.53	11.41
	Cv (%)	74.67	42.47	41.19	23.71
Assanmeyzoun	Moy	3.77	32.03	7.18	10.70
	Cv (%)	154.93	61.40	33.39	23.41
	Prob.	0.968	0.012	0.574	0.138

3.2. Species characteristic of sacred forests

3.2.1. Sacredforest of Avogbézoun

The classified forest of Avogbézoun is characterized, in decreasing order of importance, by *C. mildbraedii*, *F. thonningii* and *T. prieurianna* (Table 3). *C. mildbraedii* (30 trees / ha) is the most represented species while *F. thonningii* and *T. prieurianna* have equal densities (20 trees / ha for each species). *C. mildbraedii* and *F. thonningii* show the highest values for the other dendrometric parameters (G = 8.06 m^2 / ha and G = 9.43 m^2 / ha, respectively; Dm = 58.50 cm and Dm = 77, 50 cm, respectively; Hf = 7.00 m and Hf = 6.50 m, respectively; Ht = 14.00 m and Ht = 12.50 m, respectively).

3.2.2. Sacred Forest of Sindomè

T. prieurianna, *D. guineense* and *V. doniana* are the first three most ecologically important species in the sacred forest of Sindomè with densities of 60, 30 and 10 trees / ha, respectively (Table 3). The highest basal area is observed for *T. prieurianna* (11.54 m^2 / ha) while the lowest value is observed *D. guineense* (5.10 m^2 / ha). Regarding the other dendrometric parameters (mean diameter, bole height and total height), the highest values are observed for *V. doniana* (G = 101.00 m^2 / ha, Hf = 12.00 m and Ht = 16.00 m) while the lowest values are observed for *D. guineense* (G = 46.50 m^2 / ha, Hf = 6.00 m and Ht = 9.00 m).

3.2.3. Sacred forest of Ahouansêzoun

The three most ecologically important species in the sacred forest of Ahouansêzoun were *C. mildbraedii*, *D. guineense* and *T. prieurianna* (Table 3). The dendrometric parameters varied between 30 and 50 trees / ha for density (respectively for *C. mildbraedii* and *D. guineense* on the one hand and *T. prieurianna* on the other), between 4.50 and 14.10 m^2 / ha for the basal area (respectively for *T. prieurianna* and *C. mildbraedii*), between 33.50 and 77.00 cm for the mean diameter (respectively for *T. prieurianna* and *C. mildbraedii*), between 4.80 and 7.66 m for the bole height (respectively for *T. prieurianna* and *C. mildbraedii*) and between 8.50 and 11.33 m for the total height (respectively for *T. prieurianna* and *C. mildbraedii*).

Table 3 Species characteristic of sacred forests

Sacred Forests	Characteristic species	N (trees/ha)	G (m^2/ha)	Dm (cm)	Hf (m)	Ht (m)
Avogbézoun	*C. mildbraedii*	30	8.06	58.50	7.00	14.00
	F. thonningii	20	9.43	77.50	6.50	12.50
	T. prieurianna	20	1.71	33.00	5.50	10.50
Sindomè	*T. prieurianna*	60	11.54	49.50	9.00	12.50
	D. guineense	30	5.10	46.50	6.00	9.00
	V. doniana	10	8.01	101.00	12.00	16.00
Ahouansêzoun	*C. mildbraedii*	30	14.10	77.00	7.66	11.33
	D. guineense	30	6.90	54.00	6.00	11.00
	T. prieurianna	50	4.50	33.50	4.80	8.50
Hêkpazoun	*D. guineense*	70	4.94	30.00	4.50	8.00
	T. prieurianna	60	4.82	82.00	7.50	12.50
	T. scleroxylon	40	9.93	47.00	6.00	10.00
Assanmeyzoun	*C. mildbraedii*	90	19.48	52.50	6.00	9.50
	T. prieurianna	80	12.72	45.00	6.50	11.00
	T. scleroxylon	90	10.75	39.00	10.50	10.00

3.2.4. Sacred Forest of Hêkpazoun

In this forest, woody plants are dominated by *D. guineense* (70 trees / ha), *T. prieurianna* (60 trees / ha) and *T. scleroxylon* (40 trees / ha) (Table 3). The weakly represented species are Albizazygia, Bligiasapida, Cola giganthea, Leucaniodiscuscupanioides, Malacanthaalnifolia, Trichiliaheudelotii and Zanthoxylumzanthoxyloïdes each with 10 individuals per hectare. The basal area is higher at the level of *T. scleroxylon* (9.93 m^2 / ha) while the mean diameter, bole height and total height are higher at the level *T. prieurianna* (82.00 cm, 7.50 m and 12.50 m respectively).

3.2.5. Sacred forest of Assanmeyzoun

The most abundant species in this formation are *C. mildbraedii* and *T. scleroxylon* (90 trees / ha each) and *T. prieurianna* (80 trees / ha). On the other hand, the following species: Z. zanthoxyloides, Monodoramyristica, Morinda lucida, Albiziaferruginea, A. zygia, Antiarisafricana, Berliniagrandifolia and Bligiasapida are among the least represented, each

with 10 individuals per hectare. The best basal area and mean diameter are observed for *C. mildbraedii* while the best heights are observed for *T. scleroxylon* for bole height and *T. prieurianna* for total height.

3.3. Local importance of sacred forests

The forests investigated fulfilled the following functions:

- Socio-cultural function: some forests are cemeteries, places of initiation, old village sites where the fetishes have remained. Four of the five forests studied have their names ending with "zoun", meaning in the national language goun, "forests which harbor fetishes".
- Ecological function: the sacred forest of hêkpazoun plays an important ecological role among the five forests studied. Apart from serving as habitat for birds, palm rats, grasscutters, etc., the sacred forest of hêkpazoun serves as habitat for some large mammals such as monkeys, crocodiles.
- Religious function: the religious functions assigned to sacred forests are the health protection of local communities, happiness and prosperity.
- Economic function: the forests studied do not have an important economic function. Some illegal harvesting of timber for service wood and fuelwood intended for household consumption is carried out there. Samples often without great market value are also made for pharmacopoeia.

In terms of development, people want to enrich sacred forests with valuable species (timber, firewood, medicinal plants and sometimes with edible fruit essences). They also suggested protecting these sacred forests against wildland fires by installing regularly cleaned firewalls.

4. Discussion

This study of sacred forests has shown that they are true witnesses of the primary forest that covered the Atlantic Department in Benin. A comparative analysis of the structural characteristics of the five forests shows that they are overall better than those of the forest formations studied by other authors. In fact, the average values of the dendrometric parameters of the five sacred forests were greater than each of those obtained by Allomasso (2001), Sokpon (1995), Sinadouwirou (1997) and Amétékpé(2009) for other sacred forests. However, the Shannon index of the five sacred forests estimated at 3.6 is relatively lower than that established by Sokpon (1995) estimated at 4.81 at and that determined by Allomasso (2001) of a value equal to 4.1 in the south Benin. On the other hand, this index is clearly higher than that obtained by Sinadouwirou (1997) who worked on the dry forest of Lozoun in north central Benin. Considering the fact that the higher the value of the Shannon index, the greater the diversity (Mishra et al., 2004), it follows that the sacred forests studied have as great a diversity as that of the forests. dense above described.

These results show that despite the fact that these forests are established in a region with high demographic pressure (southern Benin), the flora richness and the specific diversity are still found in the similar standards noted by previous studies (Sokpon, 1995; Juhé-Beaulaton et al., 2005). However, a current assessment of the current area of these forests is warranted. Most studies of sacred forests are often phytosociological in nature. Several of the inventory methods used make particular use of floristic surveys (Adou et al., 2013; Arouna et al., 2017). The identification of plant species favored by these methods hides the dendrometric characteristics of the stands. Also for this study, a forest inventory was carried out. Unlike the inventory method based on recording the flora of these forests, this forest inventory made it possible to assess not only the specific richness but also the woody potential of the sacred forests. The use of this method confirms the assertion of Thiombiano et al. (2016) who consider that forest inventories are tools generally intended to assess the quantitative and qualitative importance of plant material and its evolution over time. The results of this inventory made it possible to identify the main woody species characteristic of these sacred forests.

Moreover, from the survey carried out, it appears that all the sacred forests considered in this study are placed under the authority of a traditional chief. Sacralization is the approach to conserving and protecting these forests. This mode is similar to that reported by Sokpon (1995), Kokou et al. (2011) and Arouna et al. (2017). This includes providing a permanent shelter for the ancestors' ghosts and local deities. It is the forces embodied by the guarantors of ecosystems that explain the variable level of degradation of these forests which still exist today. These same observations corroborate those of Sodégla (1993), Sokpon and Agbo (1995) and Mama and Adeniyi (2005) who worked on other sacred forests in Benin. Unfortunately, the weakening of the power of traditional leaders in a context of strong demographic growth and the massive introduction of new beliefs which convey new thoughts and which deny endogenous cultural values, the respect that the populations had for these sacred forests has failed. not ceased to erode. This state of affairs is also rooted in the delay in taking into account traditional models of forest resource management by scientists and public decision-makers (Arouna et al., 2017; Kokou, 2009). Thus, the threats weighing on these forest

genetic resources can be summed up in the destruction of the species' habitat through uncontrolled activities that consume forest space such as agriculture, anarchic logging and urbanization. as illustrated by Agbahungba et al. (1998).

5. Conclusion

The study made it possible to inventory the biological resources of five sacred forests in the Department of the Atlantic in Benin. The results obtained provide an overview of the potential of these sacred forests as well as their current state of conservation. Although these forests are of relatively small areas, they present in ecological terms, a floristic diversity and fairly good dendrometric characteristics. The study also helped to understand the perceptions of local communities on the management of these sacred forests. Indeed, these forests are of great cultural, socio-economic and ecological importance for the local populations. Overall, the study showed the need to take these neglected forest islands into account in biodiversity conservation policies and programs. The weaknesses of traditional conservation systems were identified and an integrated conservation strategy taking into account local specificities was proposed. This new approach suggests carrying out more detailed studies to illustrate the rate of degradation and reduction of the areas of these sacred forests.

Compliance with ethical standards

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The manuscript is our own research with the original data. It has never been submitted to any other journal for publication. We acknowledge that all authors have contributed significantly and agreed that the manuscript will be submitted to your journal.

Disclosure of conflict of interest

We declare that there is no conflict of interest.

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