Deuxième article : Structure patterns of gregarious communities dominated by *Khaya senegalensis* in ecological zones of Dahomey Gap in Benin

Par : A. T. B. OROU MATILO, G. S. AKOUEHOU and B. A. SINSIN

Pages (pp.) 08-17

Bulletin de la Recherche Agronomique du Bénin (BRAB) - *Numéro 81 – Juin 2017*

Le BRAB est en ligne (on line) sur le site web http://www.slire.net et peut être aussi consulté sur le site web de l'Institut National des Recherches Agricoles du Bénin (INRAB) http://www.inrab.org

ISSN sur papier (on hard copy) : 1025-2355 et ISSN en ligne (on line) : 1840-7099

Bibliothèque Nationale (BN) du Bénin

Institut National des Recherches Agricoles du Bénin (INRAB)

Centre de Recherches Agricoles à vocation nationale basé à Agonkanmey (CRA-Agonkanmey)

Service Informatique Scientifique et Biométrique (PIS-B)

01 BP 884 Recette Principale, Cotonou 01 - République du Bénin

Tél.: (229) 21 30 02 64 / 21 13 38 70 / 21 03 40 59 ; E-mail : brabinrab@yahoo.fr / craagonkanmey@yahoo.fr

Bulletin de la Recherche Agronomique du Bénin (BRAB) *Numéro 81 – Juin 2017*
BRAB en ligne (on line) sur le site web http://www.slire.net
ISSN sur papier (on hard copy) : 1025-2355 et ISSN en ligne (on line) : 1840-7099

Structure patterns of gregarious communities dominated by *Khaya senegalensis* in ecological zones of Dahomey Gap in Benin

A. T. B. OROU MATILO[3], G.S. AKOUEHOU[3] and B. A. SINSIN[4]

Abstract

The Dahomey Gap is the bioclimatic and transitional savanna zone covering a body part of the West african rainforests along the Gulf of Guinea. In purpose to examine the structure of gregarious communities dominated by *Khaya senegalensis*, we set up 20 circular plots in four forest reserves: Itchédé, Atchérigbé, Dogo-kétou and Toui Forest reserves located in two different ecological zones, Guinean and Sudano-Guinean. Twenty plots of 100m^2 each were studied in the covering zones. Although similarity in terms of main species, we found various seven secondary species among *Khaya senegalensis* dominated communities. Dendrometric parameters indicated significant ($p < 0.05$) differentiation among forest reserves whereas ecological parameters were not associated with forest subdivision. Weibull indices analysis indicated significant variation among couple of forests and then among ecological zones. Allometric relationships between height and diameter for *Khaya senegalensis* confirmed variation between these two Sudano-Guinean and Guinean Zones. In Dahomey Gap, ecological parameters for *Khaya senegalensis* are strongly correlated with climatic factors in Benin Savanna.

Key words: *Khaya senegalensis*, African savanna, spatial distribution, structural parameters, community

Modèle des structures des peuplements grégaires dominés par *Khaya senegalensis dans les zones écologiques du Dahomey Gap* au Bénin

Résumé

Le Dahomey Gap est la zone de transition bioclimatique couvrant la partie centrale des forêts denses de l'Afrique de l'Ouest tout au long du Golf de Guinée. Dans le but d'examiner la structure des peuplements grégaires dominés par *Khaya senegalensis*, 20 parcelles circulaire sont été installées dans les quatre forêts classées Itchédé, Atchérigbé, Dogo-kétou et Toui situées dans deux différentes zones agro-écologiques (Guinéennes et Sudano-guinéennes). Les 20 parcelles d'étude couvraient une superficie de 100m^2 chacune. Malgré la similarité en termes d'espèces dominantes au niveau des deux zones, plus de sept espèces secondaires ont été identifiées dans les peuplements de savanne à dominance *Khaya senegalensis*. Les paramètres dendrométriques ont montré une différentiation entre les forêts classées alors que les paramètres écologiques n'ont pas montré une dépendance avec les forêts classées, ni avec les régions agro-écologiques. L'analyse des indices de Weibull ont montré une différence significative ($p < 0,05$) entre les couples de forêts et de ce fait entre les zones écologicales. Les relations allométriques entre la hauteur et le diamètre pour *Khaya senegalensis* ont confirmé cette variation entre les deux zones Sudano-Guinéennes et Guinéennes. Dans la zone dite Dahomey Gap, les paramètres écologiques du *Khaya senegalensis* sont fortement liés aux facteurs climatiques dans les savanes du Bénin.

Mots clés : *Khaya senegalensis*, Savanes africaines, distribution spatiale, paramètres structuraux, peuplements.

INTRODUCTION

Tree structure depends on various factors in Dahomey Gap savanna because of many reasons. Generally, human pressure has been indexed as the main cause of tree structure in forests areas (Assogbadjo*et al*. 2009)expressed by recurrent fires, logging (Gaoué and Ticktin 2007), climate factors and natural assemblages. According to Lykke (1998), various human activities have implied various disturbances savanna ecosystems as constitutes a potential source for food, medicine, food, timber

[3]Dr Augustin Timothée Bio OROU MATILO, Attaché de recherche, Centre d'Études de Recherches et de formation Forestières (CERF), 06 BP 707 Cotonou, E-mail. matilorou@yahoo.fr, Tél. : (+229) 97 84 21 82, République du Benin.

Dr Ir. Gaston S. AKOUEHOU, Maître de Recherche, CERF, 06BP707 Cotonou, E-mail : gastonakouehou@gmail.com, Tél. : (+229) 97 36 76 78, République du Bénin.

[4]Prof. Dr Ir. Brice Augustin SINSIN, Professeur Titulaire, Laboratoire d'Écologie Appliquée, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 01 BP 526, Cotonou, E-mail : bsinsin@gmail.com , Tél. : (+229) 21 30 30 84, République du Bénin.

and livestock. The Dahomey Gap is the unique bioclimatic and transitional savanna region separating the West African rainforests along the southern coast of the Gulf of Guinea into two discontinuous blocks: eastern block in Nigeria and western block in Ghana and Côte d'Ivoire.

The growing population of Benin and the availability of natural resources created an unbalanced ecological context (FAO, 2001) from the south to the north of Dahomey Gap towards Sahara Desert. Generally, firewood continues to be the main sources of energy of the main part of the population. In the same side, most people continue to draw the main part of their subsistence from fruit harvesting (Gaoué and Ticktin 2007) such as shea butter, baobab tree (Assogbadjo *et al*. 2006), *Tamarindus indica* (Fandohan *et al*. 2011). In addition, Cattle breeders used continuously and illegally natural species (Gaoué and Ticktin 2008) insides forest reserves and therefore caused huge damages to woodlands and communities. *Khaya senegalensis*is therefore submitted to the harsh human and nature pressures.

On the other hand, safe and vigorous tree communities of savanna are nowadays needed to produce seeds for planting. Three years ago a national politics orientated on tree *planting* had focused on rural and urban reafforestation gave a special attention to native species such as *Khaya senegalensis*, *Terminaliasuperba*, *Afzelia africana*. It's therefore a real necessity to identify and to better understand the stand state of tree communities inside some forest reserves in the south of Benin especially of *Khaya senegalensis* which is closely involved in the life of populations (GaouéandTicktin 2007). Recently some planting forest of *Khaya senegalensis* are installed sparsely for multiple purposes (Sokpon and Ouinsavi, 2004) such as household implements, medicine, carpentry, construction

Many aspects of the species have been studied recently Gaoué and Ticktin (2009), Sokpon and Ouinsavi (2004) but few studies have been assessed. There is until now no information about the structure of communities dominated by a *Khaya senegalensis* species although the occurrence of diversities in savanna woodland. Plots indicated apparent similarity in terms of physiognomy but not other factors across forest reserves. We therefore hypothesize that some factors may have created some variability among plots. In this study, we set up some plots in purpose to (1) identify existent tree communities dominant by single species in some forest reserves (2) characterize the communities by determining dendrometric and ecological features (3) reveal the main factors which affected the differences among forest reserves. Through subplots established inside four forest reserves and dominated by *Khaya senegalensis*, this study aims to establish the basis of diameter analysis for better seed production of savanna species.

STUDY AREAS AND SPECIES

The study was carried out in four forest reserves belonging to two ecological regions: Forest reserves of Atchérigbé, and of Toui in the sub-humid region; and Forest reserves of Itchèdè, and Kétou in the humid region (Figure 1). The selected forest Reserves are located between 6°22-8°50 North and 2°24-2°80 East as indicated in Table 1.The rainfall regime in the study area is bimodal from April to June and from September to November. In this area, rainfall is about 1000 mm per year with some variations according to the forest reserve. The mean temperature varies between 25 and 29 °C and the relative humidity is about 69-97%.The African mahogany, *Khaya senegalens* is belongs to the Meliaceae family. It can grow up to 15-30m in height and 1m in diameter. It is found in humid savannah woodlands. The wood is used for multiple purposes (household implements, medicine, carpentry, construction).

Table 1. Characteristics of studied forest reserves

Name	Areas (ha)	Coordinate	Rainfall (mm)
Atchérigbé Forest reserve	2,864	7°30-7°34	1,100
		2°40-2°09	
TouiKilibo Forest reserve	43,350	8°25-8°50	1,000
		2°28-2°30	
Itchédé-Toffo Forest Reserve	191	6°59-7°01	1,150
		2°36-2°37	
Dogo-kétou Forest Reserve	42,850	6°23-7°41	950
		2°24-2°41	

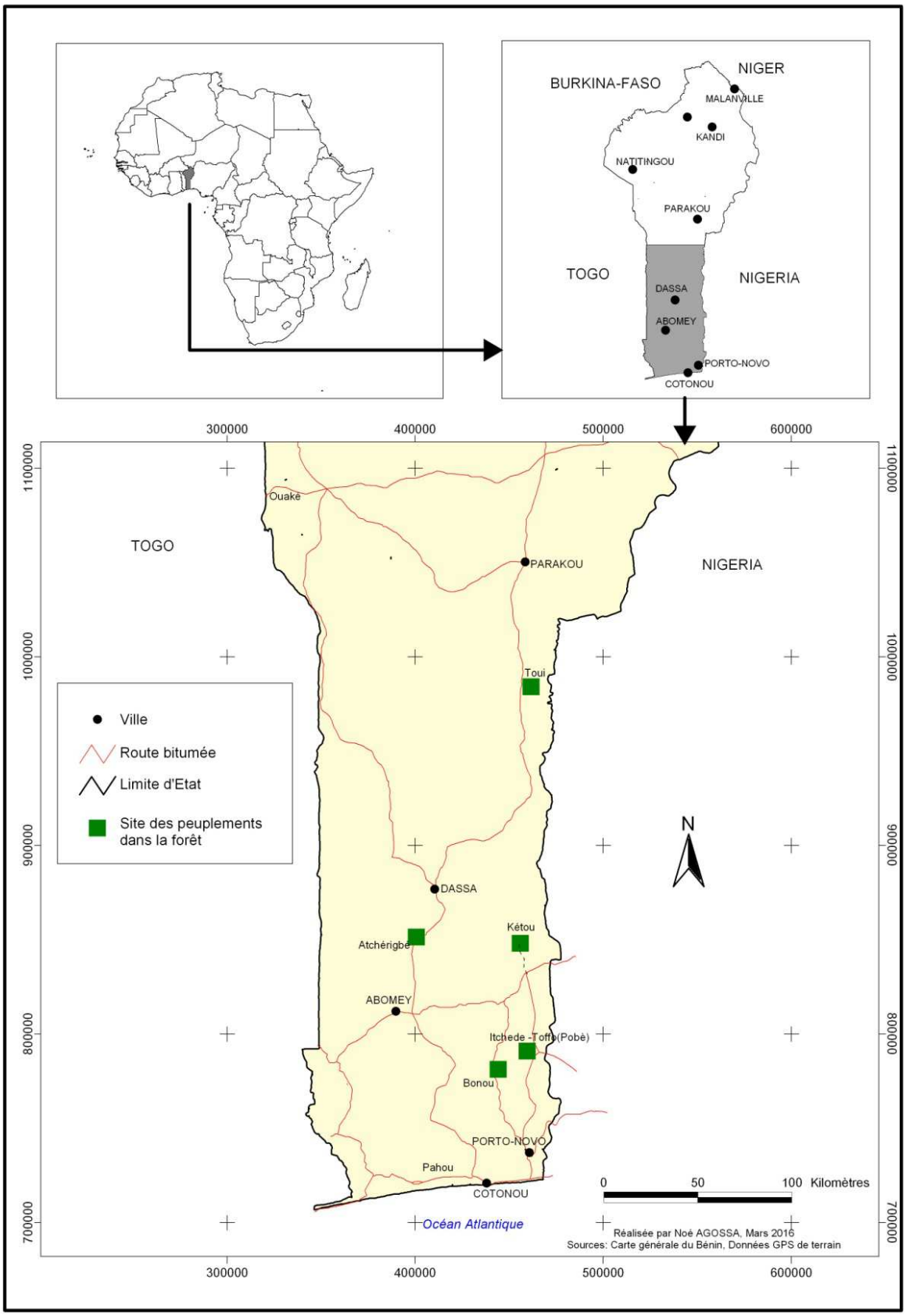


Figure 1. **Distribution of tree communities dominated by *Khaya senegalensis* in forest reserves ofDahomey Gap**

MATERIAL AND METHODS

Sampling and data collection

We explored the forests in purpose to find the gregarious population of species used for seeds. After finding the population, we set up the dimension of all the gregarious population by marked each angle of the areas in purpose to limit it. In addition we tracked by GPS all around the boundary of the population to collect mappings information. We used both ArcGis and ArcView softwares to elaborate the map of each population.

Inside each population, we set up a circular subplot of 900 m^2 where we conducted various measurements on tree individuals. Inside each subplot, the number of tree individuals is superior to 12 following (Duplat and Perrote, 1981). In each subplot, trees are marked. To quantify stand structure, field measurement of trunk girth at breast height, total tree height (H), were conducted for all individuals larger than 10cm in trunk girth. We used data of trees D ≥ 5cm. We also appreciated the texture of soil in three depths such as 10 cm depth, 20 cm depth and 30 cm depths.

Data analysis

We calculated various ecological diversity indices. In purpose to appreciate the richness of each population and to find how variable the pure population occurred, we calculated two indexes of richness: Shannon index and Pielou's index.

First, we calculated Shannon index, using the following formula: $H = -\sum_{i=1}^{s} \frac{ni}{n} \log_2 \frac{ni}{n}$, where: *n i* is the number of individuals per species *I* and n, the total number of occurred individuals inside the subplot. According to the works of Frontier, 1983, Shannon index is maximal when all individuals are equitably distributed on all species and minimal when some species are dominant in the selected area.

Secondly, we calculated the Pielou index. Pielou's index measures species evenness. This index refers to how close in numbers each species in a defined community is. This index is calculated as followed: $Eq = \frac{H}{Hmax} avec Hmax = \log_2 S$, where: H is the individual height and Hmax is the theory diversity maximal index of Shannon on the community. It's known that Pielou Index could vary between 0 and 1 with its maximal when species have similar diversity in the community and minimal when on species or a small range of species are dominant in the community following (Grallethily, 2003).

Beyond species diversity, we also focused our attention on species co-occurrence. We therefore counted the second and third dominant species in each plot in purpose to check the uniformity of secondary species inside each *Khaya senegalensis* dominated community.

In the second step, we calculated dendrometric parameters. In this group, we calculated tree density inside each subplot as the average of individuals converted per ha by using the following formula:

N = $\frac{n}{s}$, where: n is the total number of tree individuals inside a subplot, and S the total area of the subplot.

We secondly calculated the basal area for each plot and also per hectare which is a standard measure of the size-density relationship in a stand: G = $\frac{\pi}{4s} \sum_{i-1}^{n} d_i^2$, where: G in m^2/ha, d is the tree individual diameter in cm, and S is the subplot area in ha.

To test if tree density, species number, and total basal area differed significantly between the two climatic zones (Guinean and Soudano-Guinean) Kruskall-wallis test was used. To characterize size distribution of trees of each community, we used the Weibull density function following Glèlè Kakaï (2009). The shape parameter c of the Weibull distribution was computed for each replication per subplot type and the log-linear analysis revealed a good adjustment ($p > 0.05$) in many cases.

Allometric relationship Height-diameter was established for *Khaya senegalensis* trees in each forest zone by using standardized major axis (SMA) regression. A least-squares regression (LS) is often used to analyze allometric relationships. However, both size measures are subjected to natural variation and measurement error, i.e. allometric relationships cannot satisfy the assumption of LS regression as the independent size does not vary in that model.

In this study, we used (S) MATR program version 2 to calculate the standardized major axis SMA regression (Falster *et al.* 2003). Differences in slope and intercept on log-transformed regression lines were analyzed by using the F-test and analysis of covariance (ANCOVA) respectively to compare allometric regression among forest reserves.

RESULTS

Species composition

A total of 21 tree species were recorded among the four forest reserves belonging to 12 families. *Khaya senegalensis* reserves indicated various diversities with higher variability in Toui Forest reserve. About 75% of individual trees have no damage in most communities except in Toui forest reserve where 60% of inventoried species had no damage that was normal stem and canopy. Concerning other species in forest communities, the secondary species were *Miliciaexelsa*, *Antiaris toxicaria, Baphianitida, Cola gigantea*, *Ceiba pentandra* and *Dicapetalum madagascareense.* Soils were broadly ferralitic in all forest reserves.

Dendrometric and ecological parameters

We found that dendrometric parameters such as tree density, tree diameter, basal area and height were significantly different between forest reserves (Table 2). Significant variation among tree diameter of *Khaya senegalensis* were found among different forest reserves. Toui forest indicated the highest tree density (400 stems/ha) whereas Itchede forest indicated the highest mean diameter (32.29 cm). Itchede and Atcherigbe indicated the highest and similar basal area (0.102 $m^2.ha^{-1}$) among forests.

Table 2. Dendrometric and ecological parameters variation among tree communities

Parameters	Forest reserves							
	Itchédé		Atchérigbé		Dogo-Kétou		TTK	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Ecological parameters								
Species richness (S, species)	31.00		20		20.00		35.00	
Shannon Index (H)	0.98		0		0.72		1.15	
Pielou evenness (Eq)	0.31		0		0.23		0.36	
Dendrometric parameters								
Tree-density (Stem/ha)	344.000		222.000		222.000		400.000	
Diameter (cm)	32.290	8.96	34.350	8.71	23.590	42.06	17.820	20.41
Basal area (m^2/ha)	0.102	0.03	0.102	0.03	0.056	0.18	0.045	0.11
Height (m)	22.000	59.30	18.700	53.15	10.500	526.83	14.000	352.48

On the other hand TOU indicated a higher number of species but not different among forest reserves. In addition, TOU indicated the highest value of Shannon index (1.15) and the highest value of Pielou evenness (0.36). Theses previous results are not significant different among forest reserves. We then found that there is no significant variation among ecological parameters specifically for species diversity S, Shannon index H and Pielou Index Eq as indicated on Table 2.

Weibull parameters for stem diameter indicated couple of similarity between Itchede and Atcherigbe forests and between Dogo-Ketou and Toui forests (Figure 2).

The same couple of similarities have been indicated for height structure analysis using the same parameters (Figure 3).

Allometric relationships among forest reserves changed among class of sizes. When DBH < 45 cm, Itchede forest indicated the highest trend of height whereas DBH > 45 cm, *TOU* showed a trend of higher height of individuals.

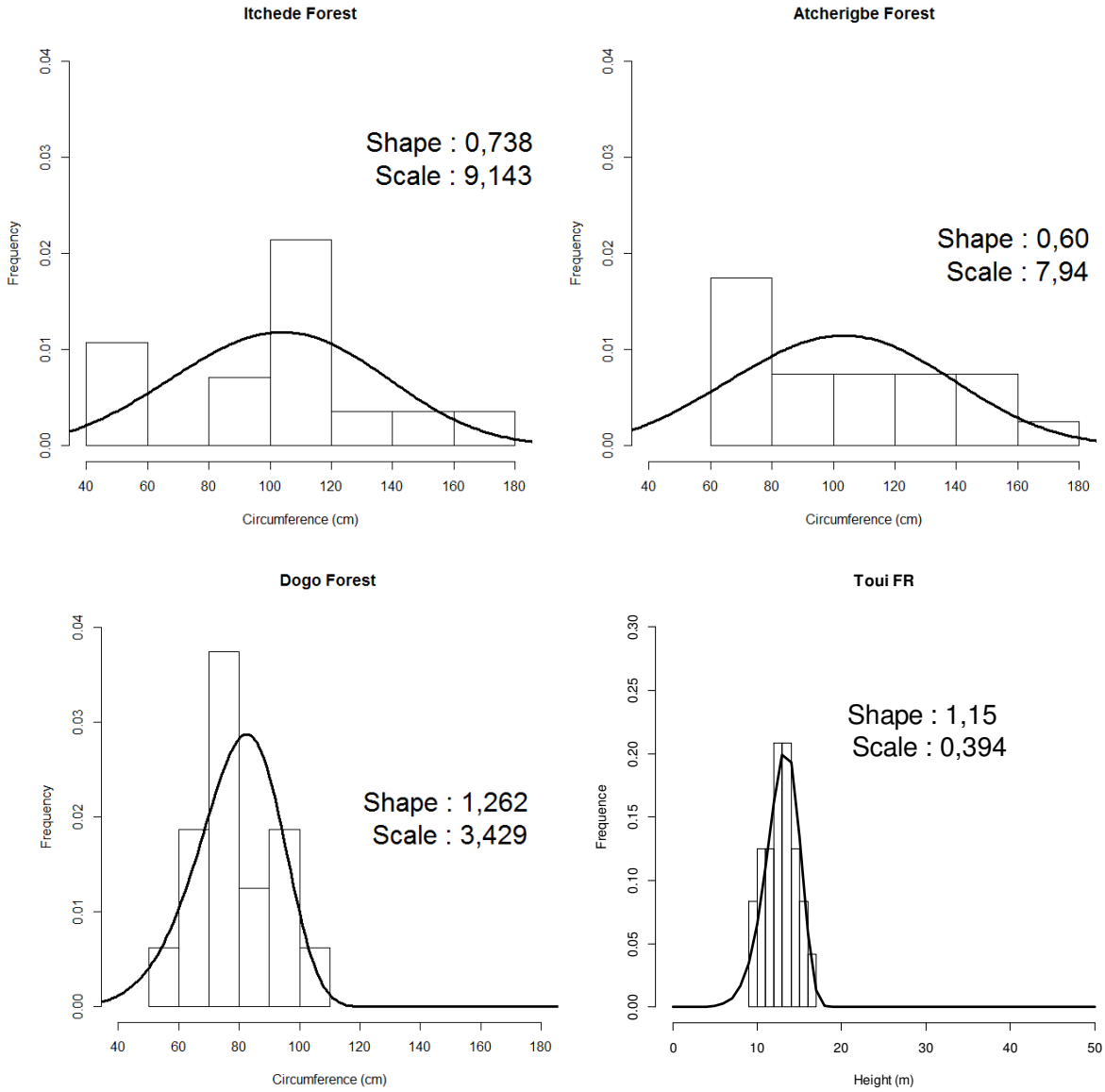


Figure 2. Stem diameter structure of *Khaya senegalensis* in mixed stands

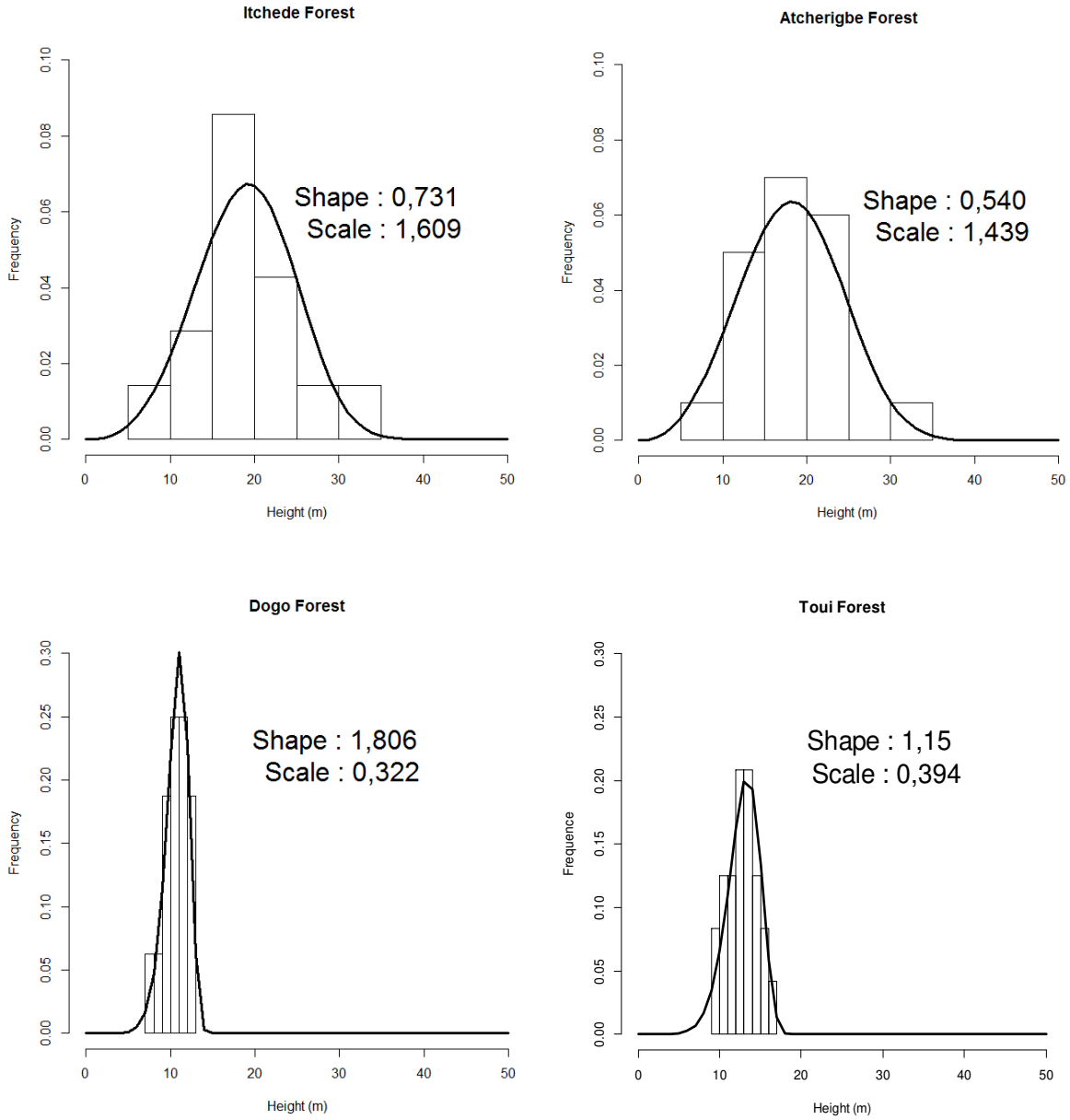


Figure 3. Height structure of *Khaya senegalensis* in mixed stands

DISCUSSION

Diversity patterns among Khaya senegalensis dominated communities

Other species have been found inside communities dominated by *Khaya senegalensis*. *Antiaris toxicari*a for Itchede Reserve, *Anogeissus leiocarpa* for Atcherigbe Reserve, *Isoberlinia tomentosa* for Dogo Reserve and *Anogeissus leiocarpa* and *Isoberlinia tomentosa* for Toui-Kilibo Reserve. Although there are similarities in terms of main species, secondary species were different throughout various forest reserves plots. Any species has not been found constant as secondary species inside *Khaya senegalensis is* dominated communites. This suggests that *Khaya senegalensis* communities are not uniform in terms of co-occurrence between both climate zones. Other studies raised the complexity of species occurrence among tropical communities. On the other hand, forest reserves located in Sudanian areas are dominated by *Anogeissus leiocarpa* or *Isoberlinia tomentosa* whereas *Antiaris toxicari* and *Terminalia superba* are dominated in Guinean areas. Although the complexity of species co-occurrences, geographical reasons might have impacted the secondary species co-occurrence in savanna woodlands. Similar results have been found connecting species co-occurrence with climate factors especially rainfall. Parmentier *et al*. (2007) have conducted a comparison between African rain forests and Amazonian rain forests and found that rainfall and temperature affect positively the species diversity. However, the level of disturbance must have affected such variability of species. The

level of disturbance include, the density of population around the area, the main activity of population such as grazing, agriculture, bush firing, and logging. Although we don't have data to prove it, this hypothesis might be effective. Houehanou *et al.*(2013) by comparing tree structure between protected areas and free access woodland induced the effect of disturbance on the structure of woodlands in savanna.

Most species index (S) is higher at TOU forest reserve located in drier area comparing to others located in wetter areas. Our result is similar to those found by Mensah *et al*. (2016) he compared spatial distribution in Benin savanna, dense forest with woodlands. He founds that woodlands indicated high species richness than dense forest. According to them, Sudanian areas are more diverse than Guinean areas.

Stand structure properties

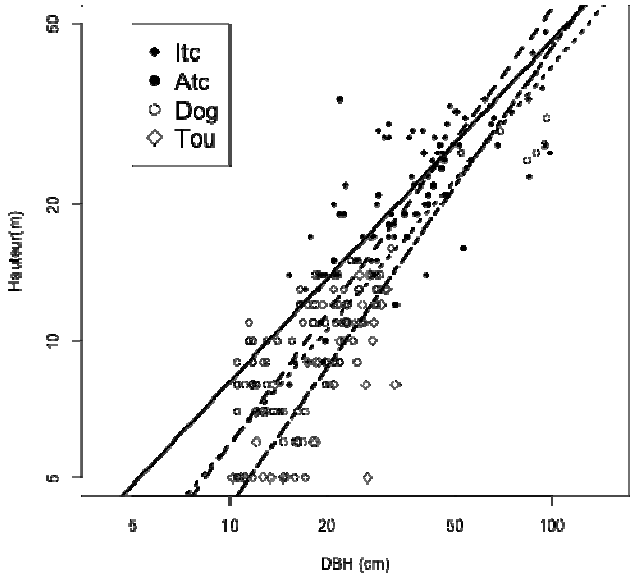
We found that tree density is higher in Toui forest (400 Individuals/ha) and lower in Atchérigbé Reserve (222 individuals/ha). These communities were very dense comparing to those studied by Fandohan *et al*. (2008) where he found for *Afzelia africana* and *Burkea Africa* respectively 128 and 142 individuals per ha. This species must have capacity to resist against several disturbances of savanna such as recurrent firing and grazing.

On the other hand, the mean diameter indicated lowest size in Toui-Kilibo Forest and highest in Achérigbé. In the same range, the mean basal area is lower (9.74 m^2/ha) in Toui Forest and higher in Itchédé Forest (28 m^2/ha). The result of Toui is similar to those reported by Orou *et al*. (2013) when they were quantifying basal area in savanna areas. The basal area is a good indicator of tree growth in height and diameter so that tree optimum conditions yielded a higher basal area. In the case of Dahomey Gap, Guinean zone indicated higher basal area than Sudan-Guinean zone. The same result has been indicated for the mean height of each plot. *Khaya senegalensis* might be one of the most representative species of savanna.

The mean diameter is lower in Toui forest (17.82 cm) whereas it's higher in Itchédé Forest reserve. This variation might be connected to various factors. The effect of rainfall variation might explain such significant variation between Guinean zones in the south and Sudan-Guinean in the center of Benin. Some studies found a similar results showing that the diameter of some species are closely related to rainfall. Sokpon and Biaou (2002), have found that diameter change with climate effects. Ouédraogo *et al*. (2015) had also demonstrated that *Anogeissus leiocarpa* structure change across climatic gradient in West Africa. However it is important to take into consideration the pressure level of communities. It's known that *Khaya senegalensis* is one of the most important species used for timber so that it was one of the most destroyed recently. Therefore, the high pressure in Toui forest where the protection was not strict might explain its lowest size in terms of diameter comparing to Itchedé which was closer to forest administration in terms of access.

This result has been longly demonstrated by Assogbadjo *et al*. (2009) for other savanna species indicating that the structure of species natural stand is correlated to anthropogenic pressure in other forest reserve in Benin. Although we don't have data to prove that the shape of plots have affected the diameter and height, we are convinced following Kolawole *et al*. (2013) that our data are reliable. Forest differentiation is also demonstrated by height-diameter relationship (Figure 4). The impact of firing can be cited in this low density. In Sudan-Guinean, forests are submitted to recurrent firing with high fire temperature. This annual firing might have affected the growth of diameters.

Our study suggests that a real conservation is needed in Sudanian region to obtain adult trees which can produce seeds for conservation in Benin. Tree communities need to be strictly protected to ensure the future of this species. However there is a need in Benin savanna to investigate efficiently the impact of enumerated factors in savanna woodlands.



Allometric relationships between dimensions of *Khaya senegalensis* architecture in different forests reserves. Solid line indicated Itchede forest (Itc), dashed line indicated Atcherigbe Forest (Atc), dash-dot line indicated Dogo Forest (Dog), and dotted line indicated Toui Forest (Tou). Lines are fitted respectively to the data from forest reserves by the analysis of covariance. All axes are in logarithmic scale.

Figure 4. Relationship between DBH (diameter, breast, height) and height on four forest reserves

REFERENCES

Assogbadjo, A.E., R. L. Glèlè Kakaï, B. Sinsin, P. Dieter, 2009: Structure of *Anogeissus leiocarpa* Guill, Perr. natural stands in relation to anthropogenic pressure within Wari-Maro Forest Reserve in Benin. African Journal of Ecology 48, 644-653.

Bonou, W., R. L. Glèlè Kakai, A. E. Assogbadjo, H. N. Fonton, B. Sinsin, 2009: Characterization of *Afzelia Africana* Sm. Habitat in the Lama Forest reserve of Benin.Forest Ecology and Management 258, 1084-1092.

Djodjouwin, L., R. Glèlè Kakaï, B. Sinsin, 2011 : Caractérisation structurale des formations naturelles enrichies en essences forestières locales: cas des vertisols de la Lama (Benin). Int. J. Biol. Chem. Sci. 5, 1628-1638

Donou Hounsodé, M.T., R. L. Glèlè Kakai, F. Azihou, B. Fandohan, A. Ouédraogo, 2016: Efficiency of inventory plots patterns for the estimation of woody vegetation recruits density in a tropical dense forest.African Journal of Ecology 53, 355-365.

Fandohan, B., E. A. Assogbadjo, R. Glèlè Kakai, B. Sinsin, 2011: Geographical distribution, tree density and fruit production of *Tamarindus indica* L. (Fabaceae) across three ecological regions in Benin. Fruits 66, 65-78.

Fandohan, B., R. L. Glèlè Kakai, B. Sinsin, D. Pelz, 2008 : Caractérisation dendrométrique et spatiale de trois essences ligneuses médicinales dans la forêt classée de Wari-Maro au Bénin. Rev. Ivoir. Sci. Technol. 12, 173-186.

Falster, D.S., D. I. Warton, I. J. Wright 2003: (S) MATR: standardized major axis tests and routines. http://www.bio.mq.edu.au/ecology/SMATR (November 2006).

Ganglo, J.C., B. De Foucault, 2006: Plant communities, forest site identification and classification in Toffo Reserve, South-Benin. Bois et Forêts des Tropiques 288, 25-38.

Gaoué, O.G., T. Ticktin, 2007: Patterns of harvesting foliage and bark from the multipurpose tree *Khaya senegalensis* in Benin: variation n across ecological regions and its impact on population structure. Biological Conservation 137, 424-436.

Gaoué, O.G., T. Ticktin, 2008: Impacts of bark and foliage harvest on *Khaya senegalensis* (Meliacea) reproductive performance in Benin. Journal of Applied Ecology 45, 34-40.

Glèlè, R. B., Sinsin, 2009: Structural description of two Isoberlinia dominated vegetation types in the Wari-Maro Forest Reserve (Benin).South African Journal of Botany 75, 43-51.

Glèlè Kakaï, R.L., B. Sinsin, R. Palm, 2008 : Etude dendrométrique de *Pterocarpuserinaceus* POIR des formations naturelles de la zone soudanienne au Bénin. Agronomie Africaine 20, 245-255.

Gnonlonfoun, I., R. L. Glèlè Kakaï, V. K. Salako, A. E. Assogbadjo, A. Ouedraogo, 2015: Structural analysis of regeneration in tropical dense forest: combined effect of plot and spatial distribution patterns. Acta Botanica Gallica: Botany Letters 162, 79-87.

Gouwakinnou, G.N., V. Kindomihou, A. E. Assogbadjo, B. Sinsin. 2009: Population structure and abundance of *Sclerocary abirrea* (A. rich) Hochst subsp. Birrea in two contrasting land-use systems in Benin. International Journal of Biodiversity and conservation1, 194-201.

Houehanou, D. T., A. E. Assogbadjo, R. Glèlè Kakai, T. Kyndt, M. Houinato, B. Sinsin, 2013: How far a protected area contributes to conserves habitat species composition and population structure of endangered African tree species (Benin, West Africa). Ecological complexity 13, 60-68.

Houéto, G., B. Fandohan, B. Ouédraogo, E. E. Ago, V. K. Salako, A. E. E. Assogbadjo, R. Glèlè Kakaï, B. Sinsin, 2012: Floristic and dendrometric analysis of woodlands in the Sudano-Guinéan zone: a case study of Belléfoungou forest reserve in Benin. Acta Bot. Gallica159, 387-394.

Lykke, A.M. 1998: Assessment of species composition change in savanna region by means of woody plant's size class distributions and local information. Biodiversity and Conservation 7, 1261-1275.

Mensah, S., A. E. Assogbadjo, V. K. Salako, E. E. Ago,R. Glèlè Kakaï, 2015: Accounting for tree spatial distribution in a comparison of plot sizes and shapes in dense forest and woodland in Benin (West Africa).African journal of Ecology 54, 1365-2028.

Ouédraogo, A., R. L. Glèlè Kakaï, A. Thiombiano, 2013: Population structure of the widespread species, Anogeissus leiocarpa (DC) Guill. &Perr. across the climatic gradient in West Africa semi-arid area. South African Journal of Botany 88, 286-295.

Orou Matilo, A.T.B., Y. Iida, Y., T. S. Kohyama. T.S. 2013: Tree species composition and stand structure of woody savanna in Dahomey Gap. Tropics 22 (2), 39-57.

Parmentier, I., Y. Malhi, B. Senterre, J. R. A. T. D. N. Whittaker, Alonso A., M. P. B Balinga, A. Bakayoko, F. Bongers, C. Chatelain, J. A. Comiskey, R. Cortay, D. M. N. Kamdem, J. L. Doucet, L. Gautier, Haxthorne, W.D., Issembe, A., Kouame, N.F., A. L. Kouka, E. M. Leal, J. Lejoly, L. Lewis, L. Nusbaumer, E. P. M. Parren,H. S. K. Peh, L. O. Philips, D. Sheil, B. Sonke, M. S. M, Sosef, H. C. T. Sunderland, J. Stropp, H. Steege, D. M. Swaine, G. M. Tchouto, S. B. Vangemerden, H. C. J. L. Van Valkenburg, H. Wöll, 2007: The odd man out? Might climate explain the lower tree Alpha-diversity of African rain forests relative to Amazonian rain forests? Journal of Ecology 95, 1058-1071.

Salako, V.K., R. Glèlè Kakaï, A. E. Assogbadjo, B. Fandohan, M; Houinato, D. R. Palm, 2013: Efficiency of inventory plots patterns in the quantitative analysis of vegetation: case study of tropical woodland and dense forest in Benin" Southern forests 75, 137-143.

Sinsin, B., O. Eyog Matig, A. E. Assogbadjo, O.G. Gaoue, T. Sinadouwirou, 2004: Dendrometric characteristics as indicators of pressure of Afzelia Sm. trees dynamics in different climatic zones of Benin. Biodivers. Conserv.13, 1555-1570.

Sokpon, N., C. Ouinsavi, 2004: Gestion des plantations de *Khaya senegalensis* au Bénin. Bois et Forêts des Tropiques 279, 37-46.

Sokpon, N., H. S. Biaou, 2002: The use of diameter distribution in sustained-use managemenent of remnant forests in Benin: case of Bassila Forest reserve in North Benin. Forest Ecology Management 161, 13-25.