Structural Study of *Isoberlinia spp* Natural Stands of Wari-Maro Reserved Forest in Benin

R. GLELE KAKAÏ[1] et A. B. SINSIN[2]

Abstract

An inventory of natural stands mainly composed of *Isoberlinia spp* was carried out in Wari-Maro reserved forest in Benin Republic to describe the structure of the stands, in tree-savannah and woodland, on the basis of some dendrometric and ecological parameters. The results of this study identified the most discriminant parameters of these two types of stands as the global dominant height (15.7 m in woodland against 12.8 m in savannah), the dominant height of *Isoberlinia* trees (16.6 m in woodland against 13.7 m in savannah), the global mean diameter (25.4 cm in woodland against 20.8 cm in savannah) and the global basal area (11.0 m^2/ha in woodland against 8.4 m^2/ha in savannah). The other parameters considered (*Isoberlinia* mean diameter, *Isoberlinia* basal area, basal area contribution, bark factor, global density, *Isoberlinia* tree density and all ecological parameters) have statistically the same value for the two type of stand. The description of the structure of *Isoberlinia spp* stands related to the dominant height shows for woodland and tree savannah, a same trend in the height class distribution of trees. Moreover, it is observed from diametric structure of stands two "J reverse" curves related to *Isoberlinia* trees and the other trees.

Key words: *Isoberlinia* spp, Wari-Maro forest, structure, discrimination, Bénin.

Etude structurale des peuplements naturels d'*Isoberlinia spp* dans la forêt classée de Wari-Maro au Bénin

Résumé

Un inventaire des peuplements naturels composés principalement d'*Isoberlinia spp* a été conduit dans la forêt classée de Wari-Maro en République du Bénin afin de décrire la structure des peuplements dans la savane arborée et la forêt claire sur la base de quelques paramètres dendrométriques et écologiques. Les résultats de cette étude ont identifié les paramètres les plus discriminants de ces deux (2) types de peuplements comme la hauteur totale dominante (15,7 m en forêt claire contre 12,8 m en savane), la hauteur dominante d'*Isoberlinia* (16,6 m en forêt claire contre 13,7 m en savane), le diamètre moyen de l'arbre (25,4 cm en forêt claire contre 20,8 cm en savane) et la surface terrière totale (11,0 m^2/ha en forêt claire contre 8,4 m^2/ha en savane). Les autres paramètres considérés (diamètre moyen d'*Isoberlinia*, surface terrière d'*Isoberlinia*, contribution à la surface terrière, facteur écorce, densité totale, densité de l'arbre d'*Isoberlinia* et tous les paramètres écologiques) ont statistiquement les mêmes valeurs pour les deux types de peuplements. La description de la structure des peuplements d'*Isoberlinia spp* liée à la hauteur dominante a montré pour la forêt claire et la savane arborée, une même tendance dans la classe de distribution des hauteurs des arbres. De plus, il a été observé pour la structure diamétrique des 2 peuplements des courbes en "J renversé" liée aux arbres d'*Isoberlinia* et aux autres arbres.

Mots clés : *Isoberlinia* spp, forêt de Wari-Maro, structure, discrimination, Bénin.

Introduction

Unlike the other west african countries, Benin is a low forested country. According to FAO (2001), the forest cover is estimated at 2,538,000 hectares, which represents 23 % of the total area of the country. Despite this situation of limited forest resources, high pressure due to anthropic factors is recorded on these resources. The valuable species as *Khaya senegalensis*, *Afzelia africana* which were in the past, well represented in the forests are now too scarce (Sinsin *et al*., 2004). The evident consequence is the massive use by the populations living along the forests, of other wood species like *Isoberlinia doka* and *Isoberlinia tomentosa* considered in the past as unvaluable. The results of forest inventories achived in most of Benin forests (Fonton, 1997) showed a quantitative importance of natural stands mainly

[1] Institut National des Recherches Agricoles du Bénin (INRAB), 01 BP 884, Cotonou, Bénin

[2] Faculté des Sciences Agronomiques, Université d'Abomey-Calavi (UAC), 01 BP 526, Cotonou, Bénin.

composed of *Isoberlinia spp* in woodlands and tree savannas as natural stands and suffer more and more of high pressure due to deforestation and uncontrolled logging (Yorou *et al*., 2001). For adequate management of these natural stands of *Isoberlinia spp*, it is necessary to describe the structure of these stands through the consideration of dendrometric and ecological parameters in Wari-Maro reserved forest.

Materials and methods

Forest inventory

Forest inventory was carried in 2003 and 2004 in woodland and tree savannah mainly composed of *Isoberlinia spp* in Wari-Maro reserved forest (figure 1).

This forest with, 107,500 ha, is located in centre of Benin Republic (112 622 km²), between 8°80-9°10N and 1°55-2°25E. This study site is located in Guine o-Soudanian transition zone defined by Aubreville (1970) as "*natural stands of Guinean wood savannah*" and by White (1983) as "*Soudanian woodland mainly composed of Isoberlinia spp*". Moreover, this reserved forest is influenced by a humid soudanian tropical climate that is characterized by two seasons: a dry season from November to March and a rainy season from April to October. August is the month where the rainfall is the most important, with 267.5 mm.

The inventory was carried out through a two-stage sampling scheme with first-degree samples having squared form of one hectare of size and identified by the co-ordinates of its centre (figure 2).

Figure 1. Tree savannah mainly composed of Isoberlinia spp

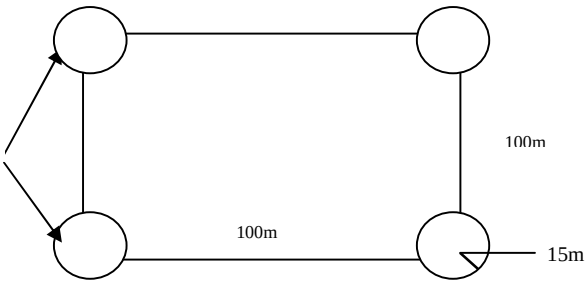

Figure 2. Localisation of the four plots in a first-degree sample

The first-degree samples, in the same natural stand are 100 m apart. Each first-degree sample is associated to four second-degree samples or sub-samples as shown in figure 2. These sub-samples, located at the tops of squared area of a first-degree sample are circular plots with 15 m of radius. A total of 24 first-degree samples are selected in savannah and 24 in forest, so 96 circular plots are inventoried in each of the two types of *Isoberlinia* natural stands (tree savannah and woodland). In each circular plot, all trees of DBH[1] more than 10 cm are measured in total height, diameter and bark thickness at 1.3 m above the ground, number of trees per species. The DBH is measured for each tree, using a compass. For a tree

[1] DBH = *Diameter at Breast Height* (1.3 *m above the ground*)

forked into w main stems under 1.3 m, its diameter d is considered as the quadratic sum of the diameters ds_i (i=1,…, w) of the main stems:

$$d = \sqrt{\sum_{i=1}^{w} ds_i^2} .$$

The total height of each of the 7 biggest trees and the height of each of the 7 *Isoberlinia* biggest trees are measured with clinometer. If x denotes the number of *Isoberlinia* trees presented in the 7 biggest trees of a circular plot, then the number of other trees measured in height is 7- x.

Description of the structure Isoberlinia natural stands

The structure of *Isoberlinia* stands is described on the basis of some dendrometric and ecological parameters. The dendrometric parameters are computed for all trees of a plot and also for *Isoberlinia* trees. The ecological parameters are computed for each first-degree sample. Otherwise, these parameters are computed for each of the two types of natural stands: tree-savannah and woodland.

The global density, N_g *and density of Isoberlinia trees,* N_{iso} : the tree density of a stand is a parameter that gives the quantitative importance of trees in the stand. The two types of density are computed through the expressions below:

$N_g = \frac{10000 n_g}{s}$ (trees/ha) and $N_{iso} = \frac{10000 n_{iso}}{s}$ (*Isoberlinia* trees/ha), where:

n_g and n_{iso} represented respectively the number of total trees and the number of *Isoberlinia* trees of the plot of size s, expressed in m^2 ($s = 225 * \pi$).

The total basal area, G (m^2/ha) *and the basal area of Isoberlinia trees per hectare*, G_{iso} (m^2/ha): the basal area per hectare is the sum of the transversal sections at 1.3 m above the ground, of all trees on the stand. The basal area is useful in the estimation of the tree volume stand. The two basal areas considered are computed as follows:

$G = \frac{10000\pi}{4s} \sum_{i=1}^{n_g} d_i^2$ and $G_{iso} = \frac{10000\pi}{4s} \sum_{j=1}^{n_{iso}} diso_j^2$, where:

d_i and $diso_j$ represented respectively the diameter of a tree i of the plot and the one related to an *Isoberlinia* tree j, expressed in m.

The global mean diameter, D *and the mean diameter of Isoberlinia tree*, D_{iso} : the mean diameter is the diameter of the mean basal area tree. These two diameters are computed using the formulas below:

$D = \sqrt{\frac{1}{n} \sum_{i=1}^{n} d_i^2}$ and $D_{iso} = \sqrt{\frac{1}{n_{iso}} \sum_{j=1}^{n_{iso}} diso_j^2}$.

The dominant height of all trees, H_d *and of Isoberlinia trees*, $Hiso_d$: The dominant height is the arithmetic mean of the 100 biggest trees per hectare. For a circular plot of 15 m of radius, this parameter is considered as the mean of the 7 biggest trees and computed for all trees, H_d and for *Isoberlinia* trees, $Hiso_d$. This parameter is a good indicator of the fertility of the stand considered.

The bark factor k : The bark is not useful in the valorisation of a tree so that the bark factor is computed to appreciate the importance of the bark in the volume tree. The computation of this factor concerns only *Isoberlinia* trees and is appreciated for each plot by:

$k=\frac{\sum d_{ui}}{\sum diso_i}$ with $d_{ui}=diso_i-2e_i$, e_i being the bark thickness measured on the tree i.

The basal area contribution of Isoberlinia trees, R : It indicates the spatial importance of *Isoberlinia* trees in the stand and computed as follows:

R =100 G_{iso}/G .

The number of species per hectare, S : it is computed for each first-degree sample.

Shannon diversity index, I_{Sh}: it measures the diversity of a stand.

$I_{Sh}=-\sum_{i=1}^{S}\frac{n_i}{n}\log_2\frac{n_i}{n}$, n_i being the number of trees of species i and n, the total number of trees presented on the first-degree sample.

Pielou evenness E : this parameter indicates the distribution of tree species abundance in the stand:

$E=\frac{I_{Sh}}{I_{\max}}=\frac{I_{sh}}{\log_2 S}$.

Data analysis consisted of analysis of variance of each parameter according to the two types of natural stands (woodland and tree savannah), by considering a partial hierarchical model, the two factors "type of stands" and "first degree sample" being respectively the principal and subordinated factors. Otherwise, the structure of *Isoberlinia* stands is described through the tree height and diameter classes distributions of the stands.

Results

Dendrometric and ecological parameters of Isoberlinia stands

The mean values and standard deviation (SD) of all parameters, for woodland and tree savannah are presented in table 1.

Table 1. Dendrometric and ecological parameters for Isoberlinia woodland and savannah

Variables	Savannah		Woodland		Probability
	Mean	SD	Mean	SD	
H (m)	12.8	3.3	15.7	2.6	**0.006**
D (cm)	20.8	3.5	25.4	5.5	**0.016**
H_{iso} (m)	13.7	2.8	16.6	2.5	**0.016**
G (m²/ha)	8.4	3.2	11.0	4.2	**0.026**
D_{iso} (cm)	24.1	6.0	29.9	8.3	0.100
G_{iso} (m²/ha)	5.1	2.8	6.7	3.1	0.103
k	0.9	0.0	0.9	0.0	0.258
E	0.7	0.1	0.7	0.1	0.262
I_{Sh} (bits)	2.9	0.4	2.8	0.6	0.328
N_g (trees/ha)	246.5	78.3	224.2	93.2	0.382
S (species/ha)	17.0	2.1	14.3	3.2	0.448
N_{iso} (Iso. Trees /ha)	117.6	64.7	114.7	86.2	0.881
R (%)	57.9	19.6	58.8	24.4	0.890

It can be noticed from this table two types of parameters: discriminant and non-discriminant parameters of the two natural stands. The discriminant parameters are those for which values are statistically different for woodland and tree savannah: the global dominant height (15.7 m in woodland against 12.8 m in savannah), the *Isoberlinia* dominant height (16.6 m in woodland against 13.7 m in savannah), the global mean diameter (25.4 cm in woodland against 20.8 cm in savannah) and the global basal area (11.0 m^2/ha in woodland against 8.4 m^2/ha in savannah). We can also noticed that, in the same stand, the value of dominant height of *Isoberlinia* trees (H_{iso}) is higher than the global dominant height (H) of the stand.

The same trend is observed as far as the mean diameter is concerned. This situation is the result of the dominance of *Isoberlinia* trees in the stands. The other parameters are non-discriminant and their values are significantly the same for the two natural stands.

Structure of Isoberlinia stands

The structure of *Isoberlinia* stands is described through the tree height structure and the diametric structure of the stands. The tree height structure for *Isoberlinia* stands takes into account the distribution of *Isoberlinia* trees height in woodland and tree savannah (figure 3) and the distribution of *Isoberlinia* trees height, compared to the other trees (figure 4).

As shown in the figure 3, a polynomial form is obtained for *Isoberlinia* trees in the two stands except the difference noticed on the mode of the two curves.

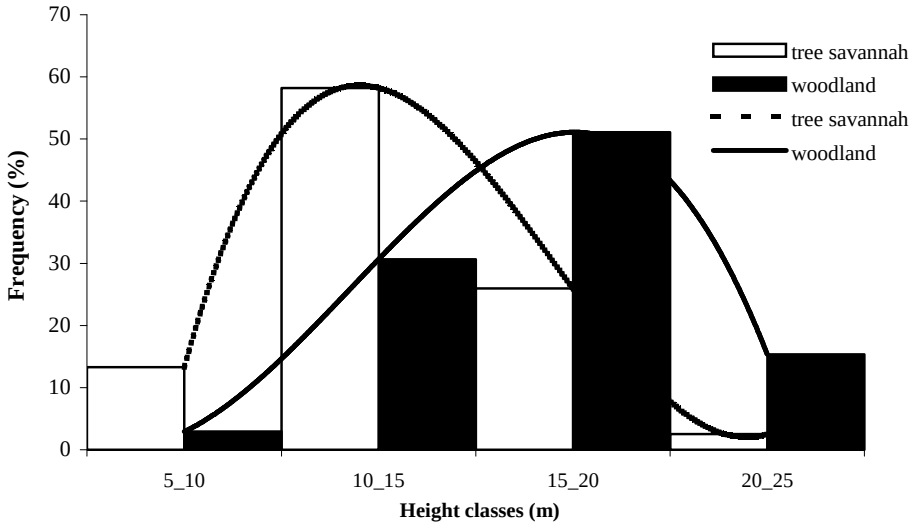

Figure 3. Tree dominant height class distribution for *Isoberlinia* tree in woodland and tree savannah

The important overlap of these two curves can be explained by an important number of trees having statistically same height values for the two natural stands (forest and savannah). The height class most represented in tree savannah is constituted of trees having height between 10 and 15 m whereas for woodlands, the trees are higher, with 15 to 20 m of height. Moreover, the highest trees are more common in woodland (18 %) than they are in tree savannah (3 %). This trend is already observed in table 1 and can be viewed as the result of the important light competition of the trees in woodland.

Otherwise, we noticed from figure 4 that the same trend as stated above is observed: two polynomial curves with different modes.

The height distribution of *Isoberlinia* trees seems to be gaussian whereas for the other trees, we observed a non-symmetric distribution, characteristic of the heterogeneous stands. The tree height class most represented for *Isoberlinia* trees is constituted of trees with 10 to 15 m whereas for the other trees, this height class is constituted of trees with 5 to 10 m. This result, as already noticed in table 1, can be viewed as another aspect of the dominance of *Isoberlinia* trees.

As far as the diametric structure of the stands is concerned, the figure 5 presents the distribution of *Isoberlinia* trees diameters compared to the one related to other trees.

As pointed from this figure, it is observed two characteristic “J reverse” curves of natural stands. The tree diameter class most represented for the two distributions is the one constituted of trees of 10 to 20 cm of diameter.

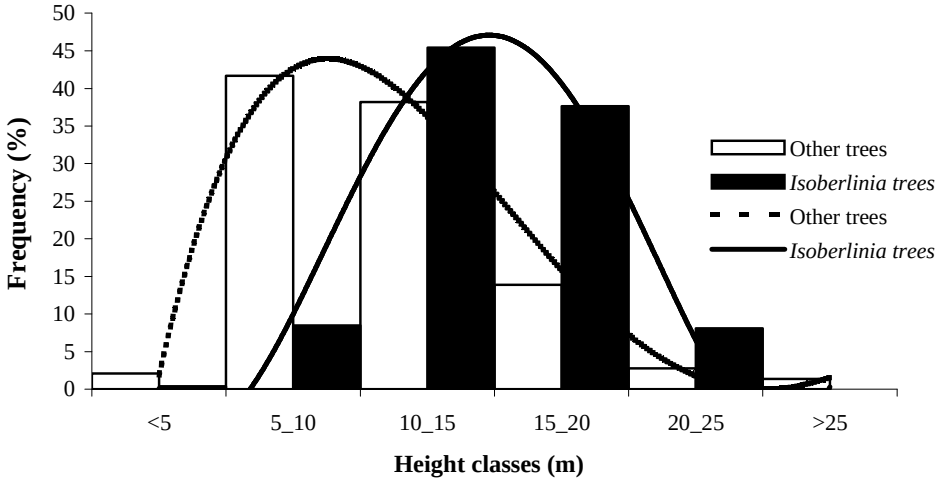

Figure 4. Tree dominant height class distribution for Isoberlinia compared to other trees

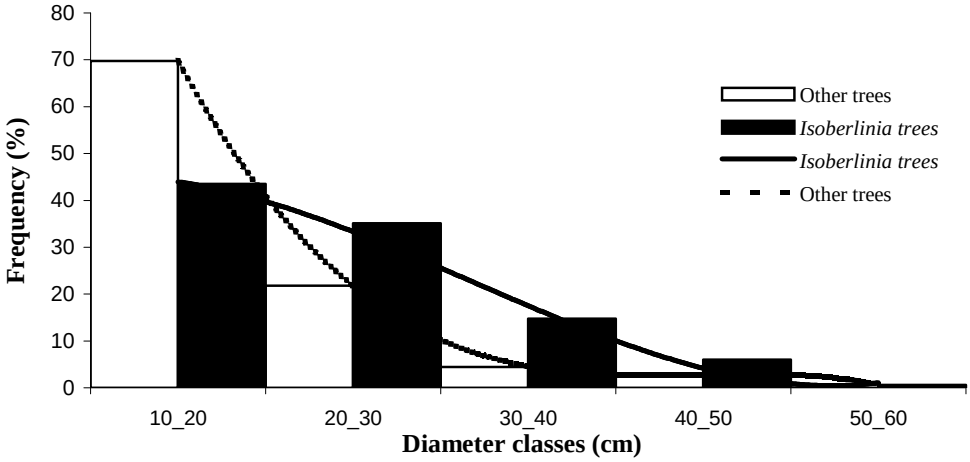

Figure 5. Diametric structure for Isoberlinia trees compared to the other trees

There are relatively more small trees of other species than for *Isoberlinia* trees. The biggest trees have 50 to 60 cm of diameter and represent respectively 0.8 % and 0.6 % of all the trees in savannah and woodland.

Discussion and conclusion

The results obtained from this study are related to the description of the structure of *Isoberlinia* natural stands in Wari-Maro reserved forest.

The two types of dominant height considered are higher in woodland than in tree savannah and is the result of more important trees competition for light in forest than tree savannah. Furthermore, in the same stand, the *Isoberlinia* dominant height is higher than the global dominant height certainly because of their gregarious character. The equal value of Pielou evenness for forest and savannah despite the large difference observed in their numbers of species per hectare can be view as the similar distribution of the species in this two stands. The low value of Pielou evenness implies the dominance of at least, one species in the stand. So, the high value obtained for Pielou evenness shows that the dominance of *Isoberlinia* trees is not in terms of species frequency but in terms of basal area contribution. Indeed, the basal area contribution of *Isoberlinia* trees in the forest is 58.4%. This dominance of *Isoberlinia* trees can also be in terms of tree dominant height. Moreover, the mean global density of 246.5 trees/ha obtained in this study is low compared to those obtained for others authors such as Akindélé (2000) and Amakpé (1998) in another forest in Benin. Nethertheless, it's important to point out the high human pressure on forestery ressources which leads to the constant decrease of trees density over the year.

The description of the structure of *Isoberlinia spp* stands related to the dominant height shows for woodland and tree savannah, a same trend in the distribution of trees in height classes. The low percentage of trees belonging to the small height classes did not automatically mean a specific pressure on *Isoberlinia* stands because of the use of dominant height instead of height of each trees. Moreover, it can be observed for diametric structure of stands two "J reverse" curves related to *Isoberlinia* trees and the other trees. This form of the curves doesn't mean automatically the presence of natural stands composed of different tree ages. Indeed, this form can result to a mixture of different homogeneous stands, as observed during the forest inventory.

Acknowledgements

This work is supported in part by the International Foundation for Science (IFS) through research grant attributed to R. Glèlè Kakaï.

References

Akindélé G. S. 2000. Possibilité d'aménagement durable de la forêt classée de l'Alibori Supérieur : Structure et dynamique des principaux groupements végétaux et périodicité d'exploitation. thèse d'Ingénieur Agronome, FSA/UAC, Bénin, 161 p.

Amakpé F. 1998. Contribution à l'aménagement durable de la forêt classée des trois rivières : composition et dynamique des principaux groupements végétaux et besoin des populations riveraines. thèse d'Ingénieur agronome, FSA/UAC, 145 p.

Aubreville A. 1970. Flore du Cameroon : légumineuses Ceasalpinoidées. Muséum National d'histoire naturelle. 16 rue Buffon, Paris 5ème , 270 p.

FAO. 2001. *Global forest resources assessment 2000*. Main report, FAO forestry paper, 140, Rome.

Fonton N. 1997. Inventaire des massifs forestiers des Monts-Kouffé, Wari-Maro et Agoua. Rapport DFRN, Cotonou, Bénin, 84 p.

Sinsin B., Eyog Matig O., Assogbadjo A.E., Gaoué O.G. & Sinadouwirou T. 2004. Dendrometric characteristics as indicators of pressure of *Afzelia africana* Sm. trees dynamics in different climatic zones of Benin. *Biodiversity and Conservation* 13(8): 1555-1570.

White F. 1983. The vegetation of Africa. UNESCO, *Nat. Ress. Res.* 20, 1-356

Yorou N. S., DeKesel A., Sinsin B., Codjia. 2001. Biodiversité et productivité des champignons comestibles de la forêt classée de Wari-Maro (Bénin). *Syst Geogr. Pl.* 71 : 613-625.