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Original Research

Influence of spatial distribution on the regeneration of the dense forest of Kalikuku, Lubero, North Kivu, Democratic Republic of Congo

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ABSTRACT:

The objective of the present study was to highlight the spatial structure of the trees and to determine its influence on the natural regeneration of the dense forest of Kalikuku. Data collection was carried out by measuring the diameter at breast height for 10 plots of 0.5 ha each. During the data analysis, the Dajoz test made it possible to determine the horizontal spatial distribution model of the two most abundant tree species in the forest, notably *Piptadeniastrum africanum* and *Ocotea usambarensis*. The chi test (χ^2) was used to compare the frequency distribution of the diameter classes for the two species under observation. To estimate the difference between the number of seedlings in aggregate areas compared to non-aggregate areas, the signed Wilcoxon test was used. In addition, the equitability index made it possible to verify the preponderance of the proportions between the diameter classes. Finally, the natural regeneration index was determined. The results showed that reforestration measures are not advisable now, before any measure to be put forth, logging and land clearing should be stopped. Also natural regeneration of forest vegetation should be favoured for better results.

Keywords:

Spatial distribution, Natural regeneration.

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INTRODUCTION

In a forest, the spatial structure of trees depends on their density and their horizontal distribution which can be random, aggregated or uniform (Bütler, 2000; Dale, 2000). Natural regeneration takes place by vegetative multiplication such as suckers from already existing strains and by germination of seeds from mature trees (Puig, 2001). Vande (2004) indicated that the spatial structure and the natural regeneration of trees are intimately linked and play an important role in the dynamics of the forest vegetation.

In addition, anthropogenic disturbances affect the spatial structure and natural regeneration of trees. Regeneration therefore constitutes the basis of the dynamic and demographic balance of plant populations ensuring the renewal of individual plants and the sustainability of species (Puig, 2001). Anthro pogenic factors are uncontrolled removals of forest resources such as extensive agriculture and forest fires that Forman and Godron (1986) and Bradstock *et al*. (2002) consider to be the most harmful given the frequency and the extent they affect in a short time.

The present study concerns the dense forest of Kalikuku which has enjoyed the status of “protected area” (Réserve Naturelle) since 1952 (Nduyire, 2007). As this forest is surrounded by various villages viz. Vwandanze, Kimbulu and the agglomeration of Lubero, the local populations cannot help but illegally take from it the varied forest resources they need. Its conservation is thus compromised. In the context of the development and sustainable management of natural forest ecosystems in general and the dense forest of Kalikuku in particular, this study is therefore necessary.

The objective of this study is to determine the density of trees in the dense forest of Kalikuku, to analyze their horizontal spatial distribution, to highlight the effect of the spatial model found on the number of seedlings and to evaluate l 'state of natural regeneration of the main tree species, which are most abundant in this forest. The central hypothesis of this research is that the spatial distribution model of trees influences the natural regeneration of the dense forest of Kalikuku.

METHODOLOGY

Description of the study site

Geographically, the Kalikuku Forest Reserve is located 7 km from the capital of the Lubero territory, in the Baswagha Chiefdom, Lubero Territory, North Kivu Province in the Democratic Republic of Congo. It extends to the west on the Butembo - Goma road, in the Luongo Group with an updated area of 89 ha. Like the agglomeration of Lubero and its surroundings, this reserve is located between 29° 30' east, 00° 30' South, with an altitude varying between 1830 m and 2000 m, thus forming part of the highlands of the territory of Lubero (Vyakuno, 2006).

The dense forest of Kalikuku enjoys an Af-type tropical climate (Köppen, 1923). It covers an area of approximately 89 ha spread over a hilly terrain with the highest peak reaching 2000 m. The soils of the Beni - Lubero region derive from the bedrock, which is mostly clay. It emerges from these works that the soils of the highlands in the extreme North - Kivu are essentially clay and weakly ferralitic, crystalline terrains of the pre - cambrian are probably lower (Nduyire, 2007). These different streams are: Kalikuku, Lusimi, Makanga, Kyamasamba, Kihuko, Mupa and that of Vwandanzi. The average annual precipitation is 1,750 mm/ha (Muhindo, 2011) .

Sampling method

To establish the list of tree species and their density in the reserve forest of Kalikuku, data collection was carried out by measuring the diameter at breast height (dbh). However, only the trees of dbh ≥ 10 cm (Blanc, 1998) were retained for the rest of the analyzes in accordance with the indications of Dallmeier (1992). These measurements took place in 10 plots spread over a stretch of 2000 m long through the forest.

Figure 1. Location map of the Kalikuku forest reserve

This is in agreement with Malaisse (1984) Malaisse (1974). The width of a plot constructed is 20 m while the length was 250 m. In each plot, the count of seedlings (dbh<10 cm) of each of the more abundant tree species was also carried out in aggregate areas (A) and in non-aggregate areas (B). Then, we counted the number of tree feet in all the plots for the species concerned. Thus, the counting of the seedlings took place in these two plots to have paired or coupled samples. The identification of tree species was based on the nomenclature of (Lebrun and Stork, (1992)**.**

Data analysis

At the level of the horizontal spatial distribution of trees, Büttler **(**2000) and Dale (2000) distinguish three horizontal spatial models: (1) the random horizontal spatial model is used when the given location of an individual is good for the growth of the plant, the probability that 'another individual finds himself in the vicinity is unaffected; (2) the aggregated horizontal spatial model when this probability is increased and (3) the uniform horizontal spatial model when this probability is reduced. In this study, the model of horizontal spatial distribution of trees was tested and confirmed by the method of Dajoz (2000) (Da) suitable for small samples. This test was applied on the basis of the number of feet of trees identified on an equal inventory area for all 10 plots (10 = pn). The rest of the analyzes were given by the values of $\lambda = 2\ \sigma\sigma^2/m$; $2\ \sigma\sigma^2$ denotes the variance and 'm' the arithmetic mean. In case if $\lambda<1$, the it is an uniform distribution; if $\lambda\approx1$, then a random distribution and $\lambda>1$ is an aggregated distribution. The value of λ varies, for a given probability rate, between confidence limits which are a function of the number of samples np.

The unit deviation of λ is significant for $\alpha=0.05$ in the case where $Da>\beta$ (in this case, $Da = \lambda - 1$ and = 0.9). The effect of aggregates on the number of seedlings was determined using the Wilcoxon (W**)** signed

Table 1. List of identified tree species and their density in the dense forest of Kalikuku

Species	NOT	%	Da
Albizia gummifera	68.0	3.1	14
Anthocleista grandifolia	6.0	0.3	2
Beilschmiedia oblongifolia	6.0	0.3	2
Bersama abyssinica	5.0	0.2	1
Bosques phoberi	13.0	0.6	3
Bridelia micrantha	8.0	0.4	2
Carapa procera	236.0	10.9	59
Catha edulis	125.0	5.8	31
Cyathea manii	111.0	5.1	28
Dialium corbisieri	212.0	9.8	53
Ficalhoa laurifolia	66.0	3.1	17
Grewia mildbraedii	42.0	1.9	11
Hallea robrostipulata	12.0	0.6	3
Ilex mitis	23.0	1.1	6
Maytenus acuminatus	32.0	1.5	8
Musanga cecropioides	11.0	0.5	3
Myrianthus holstii	12.0	0.6	3
Ocotea usambarensis	381.0	17.6	95
Paramacrolobium coeruleum	36.0	1.7	9
Parinaria holstii	56.0	2.6	14
Pentadesma lebrunii	68.0	3.1	17
Piptadeniastrum africanum	439.0	20.3	110
Polyscias fulva	65.0	3.0	16
Rapanea melanophloeoa	45.0	2.1	11
Sapium ellipticum	21.0	1.0	5
Syzygium guineense	11.0	0.5	3
Tabernaemontana	6.0	0.3	2
Trema guineensis	2.0	0.1	1
Vepris stolzii	12.0	0.6	3
Xymalos monospora	32.0	1.5	8
Total	2,163.0	100.0	541

N: number of feet per species; Da: density (number of feet/ha)

test (Scherrer, 2007). This test is the most suitable for the comparison of paired or coupled numbers, in this case, the numbers of seedlings of trees enumerated in areas of aggregates and in areas outside aggregates are on the same transect.

The state of regeneration was determined by analyzing the diametric distribution of tree individuals in diameter classes according to the rule of Blanc (1998). To test this state, the Equitability Index (R) and the ($\chi2$) chi square test were applied (Motulsky, 2002; Pielou, 1966; Scherrer, 2007). The value of 'R' is given by the formula below:

$$R = H / Hmax;$$

where 'H' corresponds to the Shannon-Weaver diversity index (observed diversity) and 'Hmax' corresponds to the theoretical maximum diversity calculated by assuming an equi-frequency of biological traits.

Finally, the value of the natural Regeneration index (Rn) was determined by the ratio of the proportion of seedlings (dbh<10 cm) to that of other tree individuals (dhp≥ 10 cm). According to Havyarimana (2009), if the value of this index is less than one, the population is in deficit; on the other hand, it is greater than or equal to one, the population is balanced. Infering the level of the distribution of tree individuals in diameter classes, the numbers continue to decrease as we move from the smallest diameter class to the largest diameter class.

RESULTS

Analysis of the density of tree species in the dense forest of Kalikuku

In the dense forest of Kalikuku, 2169 individuals of trees distributed in 30 species were identified. Table 1 presents the list and density of the identified species. The average tree density in the dense Kalikuku forest is 541 feet/ha. The two most represented species are *Piptadeniastrum africanum* and *Ocotea usambarensis* whose respective relative abundance is 20.3 % and 17.6 % and with a respective density of 439 feet/ha and 381 feet/ha.

Analysis of the horizontal spatial distribution model of trees

Table 2 shows the number of tree individuals for each of the two most abundant species on a single inventory area of 0.5 ha at the level of the 10 plots surveyed. The test of the horizontal spatial distribution model was done according to the mode proposed by

Table 2. Number of individuals for the two most abundant tree species in the Kalikuku forest

Species / Plot	1	2	3	4	5	6	7	8	9	10	λ	Da
Piptadeniastrum africanum	58	15	65	48	6	24	43	85	11	84	9.9	8.9
Ocotea usambarensis	25	55	29	41	39	47	14	35	29	67	8.1	7.1

1 to 10: number of individuals; λ: ratio of the variance to the arithmetic mean; Da: test of the horizontal spatial distribution model

Dajoz (2000) (Da). The individuals of the main tree species in the dense forest of Kalikuku are spatially distributed according to the aggregated model. Indeed, λ>1 found for the two species selected. For α=0.05, this deviation from unity is significant since the values of Da are much greater than β , i.e. Da>0.9 (Table 2).

Comparison of the number of seedlings in aggregate zones and in non-aggregate zones

Table 3 shows the number of seedlings counted in the aggregate areas and in the non-aggregate areas for the two most abundant tree species in the dense Kalikuku forest (*Piptadeniastrum africanum* and *Ocotea usambarensis*). Seedlings are more abundant in aggregate areas than in non-aggregate areas. This difference is confirmed by Wilcoxon's signed test (W) which shows that for the two species tested, the value of W is less than the value of $W_{.05}$ = 17. There is, therefore, a significant difference between the number of seedlings in aggregate areas and in non-aggregate areas. The influence of the spatial structure on the natural regeneration of the dense Kalikuku forest is therefore confirmed.

Table 3. Number of seedlings identified in aggregate zones (A) and non-aggregate zones (B)

Piptadeniastrum africanum		*Ocotea usambarensis*	
AT	B	AT	B
53	29	26	15
21	13	14	6
34	2	35	18
21	3	34	13
43	14	11	15
16	5	38	11
34	2	6	6
53	15	23	9
19	8	38	21
39	15	31	11
296	143	186	195
W = 8.2		**W = 7.5**	

Analysis of the natural regeneration of the dense forest of Kalikuku

Figure 1 shows the diametric distribution of individuals from the three most abundant tree species. The values of the equitability index confirm that for each of the two species, the class of seedlings (dbh<10 cm) contains more individuals than the other classes of diameter. Indeed, this index is equivalent to R = 0.14 for *Piptadeniastrum africanum* and to R = 0.12 for *Ocotea usambarensis*. The diameter classes therefore do not share equally the proportions of tree individuals because these values of the equitability index are close to zero.

In addition, the comparative analysis of the distribution of the proportions of the frequencies of the different diameter classes for the two tree species indicates that there is no significant difference because χ^2 = 3.1 (P>0.05). In addition, the values of the natural regeneration index reflect the equilibrium state of the dense forest of Kalikuku as they are greater than unity for all the species analyzed. Indeed, for *Piptadeniastrum africanum*, Rn = 2.6 and for *Ocotea usambarensis*, Rn = 1.1 (Table 4).

DISCUSSION

In the dense forest of Kalikuku, the analysis on the density of trees confirmed the observations of Lewalle (1972) on the preponderance of the species of *Piptadeniastrum* sp, *Carapa* sp and *Ocotea* sp in afromontane forests. In addition, the density recorded 541 feet/ha was lower than the average of 600 feet/ha observed in other dense forests of the Guineo-Congolese area, notably by Lebrun and Stork (1992). This showed that the Kalikuku forest was in the less advanced evolutionary stage than those described by Malaisse (1982). In fact, the younger the dense forest, the more numerous, closely spaced shrubs we are present which was the reverse for an old stand with large, widely spaced trees. This density obtained remained however in the same order of magnitude generally observed in tropical Africa where the density of trees in the various inventories varied between 368 and 645 feet/ha (Sonké, 1998).

The distribution of trees in diameter classes followed a steadily decreasing pace, with a maximum in the first diameter classes. Sonké (1998) attained the same conclusion in the Dja Wildlife Reserve in Cameroon. In nature, such a diametric distribution reflects a state of equilibrium (Bouko *et al*., 2007), itself synonymous with good natural regeneration (Puig, 2001). This showed that, the growth of the numerous seedlings and *via* their recruitment in the larger diameter classes (Riéra *et al*., 1998; Riéra *et al*., 1990), the Kalikuku forest would be maintained.

Analysis of the horizontal spatial distribution by the test of Dajoz (2000) showed that the individual trees in the dense forest of Kalikuku were distributed in an aggregated manner. This aggregated spatial structure in turn influenced the state of natural regeneration of this forest. The state of balanced regeneration was confirmed by the values of Rn which were greater than unity (Havyarimana, 2009).

Table 4. Values of the regeneration index of the two most abundant tree species in the dense forest of Kalikuku

Species	Np	N / A	Rn
Piptadeniastrum africanum	319	120	2.6
Ocotea usambarensis	199	182	1.1

Np: Number of seedlings (dbh <10 cm); Na: Number of mature trees (dbh ≥ 10 cm); Rn: Natural Regeneration Index

Ecologically, the aggregation of trees observed was explained either by the variation or heterogeneity of the characteristics of the environment, or by the genetic characteristics and the behaviour of living beings of the same species which often tend to group together (Bütler, 2000; Dale, 2000; Dajoz, 2006). In the dense Kalikuku forest, the aggregate pattern of the spatial distribution of trees was explained by the variation in soil characteristics. This one is of a silty structure at the tops of the hills whereas it is relatively deep and fine on the sides and towards the shallows.

In addition, the spatial structure determined the local environment around each tree (in particular the number of neighbours) and therefore its growing conditions. This local environment modifies the expression of natural processes such as growth, mortality and regeneration of the stand; this can lead to a local monospecific composition (Barot *et al*., 1999). This trend was confirmed for the dense forest of Kalikuku in which the two most abundant tree species were of different genera.

These authors pointed out that density is a particularly important concept in forest management because it provides information on the degree of occupation of space by the population. In the case of the dense forest of Kalikuku, the fact of having a balance in terms of natural regeneration means that there is no need to introduce other artificial means of repopulating the species. In addition, the density of 541 feet/ha falls within the range known in tropical Africa (Sonké, 1998). However, this density of trees observed in the dense Kalikuku forest showed that there is intense competition between these trees for resources.

The behaviour of the juvenile stage of the dense forest of Kalikuku provided more information about the future of this ecosystem. Indeed, the regeneration of a species of tree is subject to the density and spatial distribution of individuals (Jean, 1997). Thus, the preponderant proportion of seedlings found in the dense forest of Kalikuku is a sign of a balanced regeneration. This conclusion corroborates the observations of Kohyama (1991), Kubota (1995), Reader *et al*. (1995) and Berkowitz *et al*. (1995).

CONCLUSION

In conclusion, we note that the aggregated horizontal spatial structure of the trees of the dense forest of Kalikuku promotes natural regeneration in a balanced state despite the many anthropogenic disturbance factors exerted on this ecosystem.

The present analysis constitutes an important argument which argues in favour of taking integral protection measures aimed at maintaining good natural regeneration of this forest. It is therefore not needed to proceed with the introduction of species by reforestation in the dense forest of Kalikuku. These protective measures would relate to maintaining the integrity of the forest, in particular by protecting it from any action that could disturb the spatial structure of trees, such as logging and land clearing.

REFERENCES

Barot S, Gignoux J and Menaut JC. 1999. Seed shadows, survival and recruitment: how simple mechanisms lead to dynamics of population recruitment curves. *Oïkos*, 86(2): 320-330.

Berkowitz AR, Canham CD and Kelly VR. 1995. Competition vs. facilitation of tree seedling growth and survival in early successional communities. *Ecology*, 76 (4) : 1156- 1168.

Blanc L. 1998. Les formations forestières du Parc National de Cat Tien (Viêt-Nam) : caractérisation structurale et floristique, étude de la régénération naturelle et de la dynamique successionnelle. Thèse de doctorat, Université Claude Bernard, Lyon 1, 207 P.

Bouko SB, Sinsin B and Soulé GB. 2007. Effets de la dynamique d'occupation du sol sur la structure et la diversité des forêts claires et savanes du Bénin. *Tropicultura*, 25(4): 221-227.

Bradstock RA, Williams JE and Gill AM. 2002. Flammable Australia. The fire regimes and biodiversity of a continent. Cambridge University Press, Melbourne, 488 P.

Bütler R. 2000. Analyse de la distribution spatiale d'objets dans un paysage. Fiche d'enseignement, Laboratoire de gestion des écosystèmes (GECOS), Lausanne, 18 P.

Dajoz R. 2000. Précis d'écologie. Dunod, Paris, 615 P.

Dajoz R. 2006. Précis d'écologie. 8th édition.

Dunod, Paris, 631 p. Roger, D. A. J. O. Z. 2006. Précis d'écologie. Ed. Dunod, Paris, 434 P.

Dale, M.R.T., (2000). Spatial Pattern Analysis in Plant Ecology. Cambridge University Press, 326 P.

Dallmeier F. 1992. Long term monitoring of biological diversity in tropical areas: methods for establishment and inventory of permanent plots. Man and biosphere digest 11, United Nations Educational, Scientific and Cultural Organization, Paris, 72 P.

Forman RTT and Godron M. 1986. Landscape Ecology. John Wiley and Sons, New York, 619 P.

Havyarimana F. (2009). Impact de la distribution spatiale des espèces arborescentes sur la diversité végétale dans la réserve naturelle forestière de Bururi (Burundi). Mémoire, Université Libre de Bruxelles, + Annexes, 55 P.

Jean D. 1997. Manuel d'aménagement forestier: gestion durable et intégrée des écosystèmes forestiers. Tec & doc -Lavoisier. Paris - Office national des forêts, 239 P.

Kohyama T. 1991. A functional model describing sapling growth under a tropical forest canopy. *Functional Ecology*, 5 : 83-90.

Köppen WP. 1923. Die klimate der Erde-Gundriss der Klimakunde. Walter de Gruyter and Co., Berlin, Leipzig, 369 P.

Kubota Y. 1995. Effects of disturbance and size structure on the regeneration process in a sub-boreal coniferous forest, Northern Japan. *Ecological Research*, 10(2): 135-142.

Lebrun JP and Stork AL. 1992. Enumération des plantes à fleurs d'Afrique tropicale. Volume II. Chrysobalanaceae à Apiaceae. Genève: Conservatoire et Jardin botaniques de la Ville de Genève, 257 P.

Lewalle J. 1972. Les étages de végétation du Burundi occidental. Bulletin du Jardin Botanique National de Belgique, Volume 42, 173 P.

Malaisse F. 1974. Quelques méthodes d'étude de la structure en forêt. Exemple d'application au miombo zaïrois, écosystème tropical. Dans: La pratique de l'écologie. Place du champ de Mars, Bruxelles, 104-118 P.

Malaisse F. 1982. Evolution of the woody structure in a regressive zambezian succession: dry evergreen forest-open forest-wooded savanna. Revue internationale de géologie, de géographie et d'écologie tropicales, 6(4).

Malaisse F. 1984. Structure d'une forêt sèche à feuillage persistant bordant le fleuve Zambèze dans les environs de Lubumbashi (Zaïre). *Bulletin de la Société Royale Botanique de Belgique*, 117: 428-458.

Motulsky HJ. 2002. Biostatistique: une approche intuitive (Sciences et méthodes). De Boeck and Larcier, 484 P.

Muhindo S. 2011. Le contexte urbain et climatique des risques hydrologiques de la ville de Butembo (Nord Kivu/RDC). université de Liège, Liège, Belgique, 273 P.

Nduyire 2007. La détermination de différentes contraintes de la production de la culture de maïs en cité de Lubero et ses environs.

Piélou EC. 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical Biology*, 10(2): 370-383.

Piug H. **2001**. Diversité spécifique et déforestation: L'Exemple des forêts tropicales humides du Mexique. Bois et Forêts des Tropiques, 37 P.

Reader RJ, Bonser SP, Duralia TE and Bricker BD. 1995. Interspecific variation in tree seedling establishment in canopy gaps in relation to tree density. *Journal of Vegetation Science*, 6(5): 609-614.

Riéra B, Pélissier R and Houllier F. 1998. Caractérisation d'une mosaïque forestière et de sa dynamique en forêt tropicale humide sempervirente. *Biotropica*, 30(2): 251-260.

Riéra B, Puig H and Lescure JP. 1990. La dynamique de la forêt naturelle. Bois et Forêts des Tropiques, 219: 69-78.

Scherrer B. 2007. Biostatistique. Volume 1, 2ème édition, Gaëtan Morin (éditeur), Montréal, 816 P.

Sonké B. 1998. Etudes floristiques et structurales des forêts de la réserve de faune du dja (Cameroun). Thèse de doctorat, Université Libre de Bruxelles, 256 P.

Vande WJ. 2004. Forêts d'Afrique centrale. La nature et l'homme. Editions Lannoo SA, Tielt-Belgique, 367 P.

Vyakuno KE. 2006. Pression anthropique et aménagement rationnel des hautes terres de Lubero en RDC. Rapports entre société et milieu physique dans une montagne équatoriale, Tome I, Thèse, Université de Toulouse II, Département de géographie et aménagement, 144 P.

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