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Original Research

Evaluation of natural regeneration of *Prunus africana* (Hook. f.) Kalkman in the operating sites of the province of North Kivu at the Democratic Republic of Congo

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ABSTRACT:

The objective of this study is the natural regeneration of the *Prunus africana* in its distribution area at North Kivu province, for its optimal preservation and enhancement. Data collection was performed by measuring heights for different stages of young seedlings and diameter at its breast height for adult trees along the plot. To estimate difference between the number of seedlings at different sites, the Wilcoxon signed test was used. In addition, the equitability index was used to check the balance of proportions between the class heights. Finally, the index of Shannon-Weaver diversity and evenness of natural regeneration were calculated.

Keywords:

Prunus africana, Biodiversity, Distribution of plants, Regeneration, African montane forests.

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INTRODUCTION

Prunus africana (Hook. f.) Kalman (Rosaceae) generally known under the name pygeum is a tree that grows in African montane forests between 1500 and 3000 m, and on the volcanic soils as climatic altitude trees. Its range encompasses the Ivory Coast, Bioko, Sao Tome, Ethiopia, Kenya, Uganda, Burundi, Rwanda, South Africa, Madagascar, Congo, Cameroon and Democratic Republic of Congo (Kibungu, 2008). In the Democratic Republic of Congo, *Prunus* was reported at four provinces namely Orientale, Katanga, North Kivu and South Kivu. In its range, populations of *Prunus* are discontinuous and fragmented (Kibungu, 2008).

The natural regeneration mechanisms of these ecosystems are an essential aspect of their biology. Yet for these ecosystems, there is insufficient information in many areas across the developing world as they give useful information for better management of natural resources. Furthermore, knowledge of these mechanisms would guide the restoration of forests variously disturbed by human activity and would define the real development opportunities, especially in the area of forest plantations. Preliminary appropriate decisions to rational improvements would require knowledge of geo-spatialisation. Cuma *et al.* (2014) believed that this spatial distribution in the stages of development allows one hand to understand the mechanisms of recruitment in populations of native trees and also to deepen knowledge about biological strategies by which they maintain their populations. Hubbell (1979), showed that different species distribution patterns are related to their modes of dissemination.

The regeneration of rainforests is a big concern for many foresters Catinot (1965) and Catinot (1966); (Leroy, 1976; Rollet, 1983; Bariteau 1992; Dupuy *et al*., 1998). The adaptation and its productivity is a necessity to ensure sustainability of its massive production (Dupuy *et al*., 1998).

It is also necessary to take into account, the monitoring of developmental plans, the response of the population to the exploitation of species, either at the regeneration or acquired in the future settlement (Durrieu, 1999). However, the lack of biological and ecological knowledge of these species is a limitation and a great handicap for the proper management of these forest resources (Bibani *et al*., 1998).

Fournier and Sasson (1983) found that many species make up the African rainforest causes indeed a variability almost infinite in its composition and causes enormous difficulties about the synthetic study of its dynamics. Also we should admit that it is still unclear that most of the rules that guide regeneration in place. This study is designed to collect data on the natural regeneration of operating sites such as Mwenda, Lume, Buligha, Ibathama, Mangurejipa, Walikale 1 and Walikale 2 at North Kivu Province, Democratic Republic of Congo.

The goal of this study is the quantitative estimation of regeneration of *Prunus africana* at various operating sites.

Some issues that have contributed to make this work are:

- The density of seedlings in the operating sites of *Prunus africana?*
- The distribution of seedlings according to the visible adult feet?
- Interest and originality of the study data and its solid foundation on regeneration of *Prunus africana* which is not yet documented?

MATERIALS AND METHODS

Study area

The areas selected for the survey are located in the territory of Beni, community-sector of Ruwenzori Lubero at the a region of Walikale in Bapere and Wanianga. It is characterized by a succession of rocky peaks in places separated by rivers and crevices. The altitude varies between 1200 (Mwenda Buligha and Lume Ibathama) and 2300 meters for the surveyed regions. The peak Marguerite, located in this region, is at an altitude of 5120 m. These hills are separated by deep ravines often impassable whose combination with the hill offers a panoramic view of a heavily corrugated region and convolution. The more rugged nature of this region, has made it difficult and arduous opening transects often failed to establish the circular plots.

The local climate showed high humidity and spontaneous rain at the Ruwenzori massif. Fog effects, which increases rainfall are visible at Mwenda and elsewhere. The dry season is short, it is only from December to February. The average temperature varies between 22°C and 25°C. The month of July is one that records the least precipitation, while the month of November recorded the highest rainfall of the year, i.e., 170 mm. The hottest month is March and the month July seems to be with less hot.

Methodology

The appreciation of natural regeneration of *P. africana* is studied with its enumeration and classification of different growth phases from the juvenile to the stage with senal (a diameter less than 10 cm). The readings of the coding system on regeneration are as follows: (i) S1: seedling or plantlet (height less than 0.30 m); (ii) S2: seedlings or plantlets of between 0.30 and 1.5 m in height; (iii) S3: seedling height rods or greater than 1.5 m and less than 10 cm diameter. The state of regeneration was determined by analyzing the diametric distribution of individuals of trees in diameter classes according to Vyakuno (2006). The index of evenness (R) was tested as given by Motulsky (2002) and Scherrer (2007). The value of R is given by the formula (1):

$$R = H / H\ max \quad (1)$$

where, H: corresponds to the Shannon-Weaver (observed diversity) diversity index; H max: is the theoretical maximal diversity calculated assuming a equifrequency of biological traits. Thus, counting of seedlings took place in those ten plots for paired samples or coupled *Prunus.* The identification was based on Lebrun and Stork (1997).

Data analysis

While analysing the horizontal spatial distribution of trees, Bütler (2000) and Dale (2000) identified three horizontal spatial models: (i) The random horizontal spatial model- the given location of an individual shows, the probability that another individual finds its proximity that it is not affected; (ii) the aggregate horizontal spatial model- the likelihood the species are increased, and (iii) the uniform horizontal spatial model where the probability is reduced. In this study, the model of horizontal spatial distribution of trees has been tested and confirmed by the method of Dajoz (2000) suitable for small samples. This test was applied based on the number of trees identified in feets on an even surface to inventory for all 10 plots.

Finally, the value of the Natural Regeneration Index (*Rn*) was determined by the ratio of the proportion of the seedlings to the other individuals of mature trees. According to Havyarimana (2009), if the value of this index is less than one, the population is deficient; if it is greater or equal to one, the population is balanced, that is to say at the level of the distribution of individuals of trees in diameter classes, the numbers continues to decline gradually and when one passes from the class of smaller diameter than the larger diameter classes.

RESULTS AND DISCUSSION

Density of the seedlings

Table 1 shows the different densities of seedlings according to the height classes. As shown in the Table 1 the site Lume has the highest density (53.4 plants/ha), followed by Walikale 1 and 2 (42.2 and 45.0 seedlings/ha) Buligha (43.6 seedlings/ha) and Mwenda

Table 1. Density of operating sites according to the height of the classes

S. No	Sites	Seedlings							
		(S1) (<30 cm)		(S2) (30cm-150cm)		(S3) (Sup 150 cm <10 cm DHP)		Total	
		Fo	F/ha	Fo	F/ha	Fo	F/ha	Fo	F/ha
1	Mwenda	98	19.60	54	10.8	11	2.2	163	32.6
2	Lume	105	21.00	121	24.2	41	8.2	267	53.4
3	Buligha	93	18.60	91	18.2	34	6.8	218	43.6
4	Ibathama	75	15.00	96	19.2	16	3.2	187	37.4
5	Mangurejipa	65	13.00	32	6.4	5	1.0	102	20.4
6	Walikale1	102	20.40	77	15.4	32	6.4	211	42.2
7	Walikale2	111	22.20	89	17.8	25	5.0	225	45.0
Total	**9**	**649**	**129.8**	**560**	**112.0**	**164**	**32.8**	**1373**	**274.6**

and Mangurejipa showed less representation (32.6 and 20.4 seedlings/ha) for all height classes.

For <30 cm Walikale2 achieved 22.2 plants/ha; monitoring Lume 21 seedlings/ha, Walikale1; 20 plants/ha and 20.4 Buligha plants/ha. In the class of height from 30 to 150 cm, Lume realized 24.2 seedlings/ha, followed by Ibathama (19.2 seedlings/ha) Buligha (18.2 seedlings/ha) and Walikale2 (17.8 plantlets/ha).

For classes >150 cm Lume gave a density of 8.2 seedlings/ha, *Buligha* showed 6.8 plants/ha and in Walikale 1 with 6.4 plants/ha and Walikale 2 with 5.0 seedlings/ha. We see that these densities gradually decrease with height

Tree distribution in the operating sites

Distribution of seedlings by height in the operating sites

Figure 1 shows the distribution of seedlings at different operating sites. It is clear from this figure that all sites have a significant proportion of the stratum <30 cm with more than 10 plants/ha and a smaller proportion of Manguredjipa, Mwenda and Ibathama in the stratum of >150 cm with less than 5 seedlings/ha and other sites with more than 5 seedlings/ha.

Distribution of adult trees in the mining sites

Figure 2 shows the distribution of trees at operating sites. It is clear from this figure that all operating sites with the number of individuals at the stage senile are highly visible at Lume, Walikale 1 (21 feet each). They followed Mwenda (18 feet) with

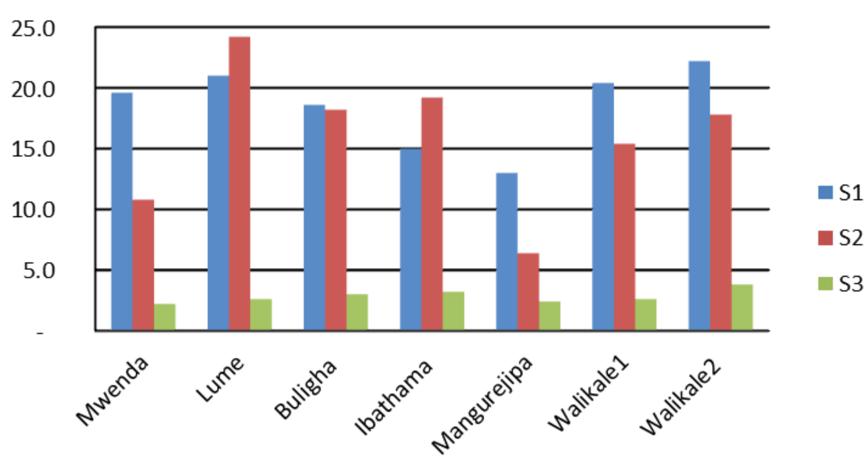

Figure 1. Distribution of seedlings in the mixed dense forest

Table 2. Values of the tree index and regeneration of *Prunus africana* at the operating sites.

S. No	Sites	Number of seedlings	Number of adults	Natural regeneration
1	Mwenda	33	4	8.3
2	Lume	53	4	13.3
3	Ibathama	44	2	22
4	Buligha	37	3	12.3
5	Mandurejipa	21	1	21
6	Walikale 1	42	4	10.5
7	Walikale 2	45	3	15

Np: number of seedlings (S>150 cm <10 cm in diameter); Na: number of adult trees (DBH ≥ 10 cm); Rn: natural regeneration index.

Ibathama (15 pieds) and Buligha (11 feet).

Analysis of natural regeneration of the dense forest Kalikuku

Table 2 shows the height distribution of tree individuals in the various operating sites *Prunus africana.* The values of equitability index confirms that for each site, the class of seedlings (dbh >150 cm dbh to <10 cm dbh) contains more individuals. In addition, the values of the natural regeneration index indicated steady state *Prunus africana* in all different operating sites, that they are greater than one.

Seedling density per production site

Table 3 shows that seedling stage S1 represented on an average 18.5 followed by S2 and S3 and individuals at the senile stage come in third with an average of 10.1 feet/hectare.

DISCUSSION

In the operation sites of *Prunus africana,* analysis of tree density confirms the observations of Lewalle (1972) on the balance of it in its range. Navarro *et al.* (2008) found 7.18 plants per hectare in their study on forest structure in the harvested sites of the Afromontane forests and *Prunus africana* on Bioko (Equatorial Guinea). This density is very high and reflects a forest rich face. This shows that with the growth of seedlings and many through their recruitment in larger diameter classes (Riera *et al*., 1990; Riera *et al*.,1998), the forests of eastern *Prunus* at different sites would be maintained.

Analysis of the horizontal spatial distribution by the test Dajoz (2000) showed that *Prunus africana* trees are distributed in an aggregated form. This aggregated spatial structure in turn affects the state of the natural regeneration of the forest. The balanced regeneration

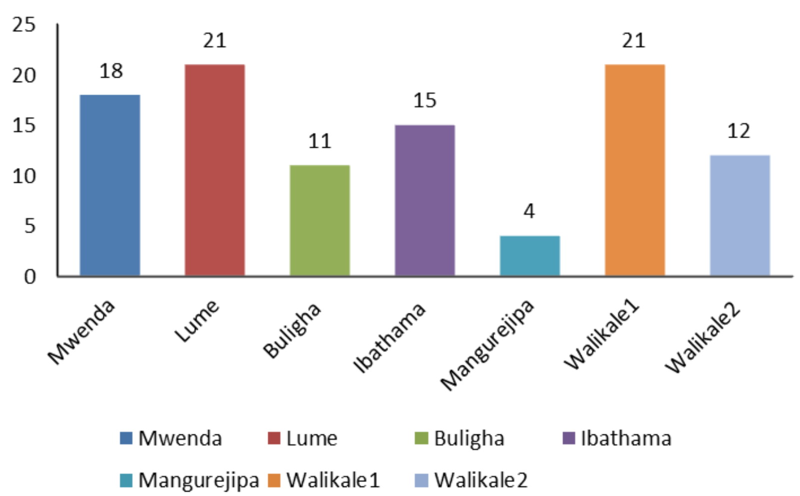

Figure 2. Distribution of visible adult trees

Table 3. seedling density of the *Prunus africana* at its cultivation sites

S. No	Species	Mwenda	Lume	Buligha	Ibathama	Mangurejipa	Walikale 1	Walikale 2	Average/ha
1	S1	19.6	21	18.6	15	13	20.4	22.2	18.5
2	S2	10.8	24.2	18.2	19.2	6.4	15.4	17.8	16
3	S3	2.2	2.6	3	3.2	2.4	2.6	3.8	2.8
4	Adult V	3.6	4.2	2.2	3	0.8	4.2	2.4	2.9
5	Total	36.2	52	42	40.4	22.6	42.6	46.2	40.3
6	Average	9.05	13	10.5	10.1	5.65	10.65	11.55	10.1

condition confirmed by Rn values were all above the Havyarimana (2009) unit. Ecologically, the aggregation of trees observed indicated either the change or the heterogeneous characteristics of the medium or by the genetic characteristics and behaviour of living organisms of the same species, which often tend to cluster (Büttler, 2000); (Dale, 2000); (Dajoz, 2006). The formation of clusters were due to the shape of the seed in the drupe (Sarcochore) and whose wind dispersal would be limited because of its weight; zoochory was the possibility for a remote dispersion. Cuma *et al.* (2014) in the study of the stages of development and regeneration of *Pterocarpus angolensis* in natural population at the Miombo Katanga, argued that the aggregate distribution with positive dependence of seedlings and adults probably depended on the morphology of the diaspore of this species which made its limited dispersion. Indeed, as the diaspore is heavy, more dispersal distance is short and therefore there is formation of large aggregates.

Dubourdieu (1997), in his study of phenology and natural regeneration in plantation and natural forest of *P. africana,* found that regeneration is almost absent at an average altitude that would be justified by a dense undergrowth that provides a barrier against light and an insulator between the ground and the seeds of *P. africana.* The stage of regeneration at high altitude is high, this is justified by the fact that conditions are favourable for optimal lighting necessary for the germination of most of the seeds. Indeed, at high altitudes and especially steeply causing the fall of a few trees, the holes created in the canopy are conducive for seed germination.

In the sites of *Prunus,* the aggregate model of the spatial distribution of trees is explained by the variation of its soil characteristics. This is a stony structure into the hills while it is relatively deep end and on the sides and towards the shallows. Moreover, the spatial structure determines the local environment around each tree (in particular the number of neighbouring trees) and therefore its growing conditions. This local environment modifies the expression of natural processes such as growth, mortality and regeneration of the settlement; this can lead to a local composition monospecific (Barot *et al*., 1999). These authors stated that the density is a particularly important concept in forest management because it provides information on the degree of occupation of space by the stand.

Thus, the major proportion of seedlings found in various mining sites were a sign of a balanced regeneration. This is in agreement with the observations of Kohyama (1991), Kubota (1995), and Berkowitz *et al*. (1995).

CONCLUSION

Aggregate horizontal spatial structure of forest promotes *Prunus africana* trees natural regeneration in a balanced state in spite of the many factors of human disturbance exerted on the ecosystem. This analysis is an important argument in favour of taking full protective measures for the maintenance of good natural regeneration of the forest. To ensure the medium and long term, the future of tropical production forests, objective scientific knowledge on the dynamics of natural regeneration prove important. Part of the conclusion here would integrate information related to the mapping.

The study of the physiology of species characteristics and especially their light requirements during successive stages of growth should allow to model the growth of helpful individuals in bright gradients. In the spirit of the preservation of genetic heritage, we continue the analysis of phenomena related to the seed dispersal, its conservation and germination.

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