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Effect of trees' basal area and substrate on the regeneration in the Rubi Tele Domaine de Chasse mature forest

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Abstract

The aim of the present study is to analyze the effect of trees' basal area and substrate on the regeneration in the Rubi Tele Domaine de Chasse (RTDC) mature forests. The RTDC straddles the Tshopo and the Bas-Uélé provinces in the North-Eastern part of the Democratic Republic of the Congo (DRC). A census of all shrubs and arborescent individuals with 1 cm diameter at least was realized in twenty (20) plots of 0.05 ha (100 m X 5 m) each. Simultaneous accumulation of area showed in the understory layer the appearance of 95 species (2195 individuals) in the mature forest established on Periodically Flooded soils (PI) and 82 species (3192 individuals) in the mature forest established on dry gravelly soil (Gr). The mean rate of the arborescent basal recovery to the inventory area of each plot (0.05 ha) was 2.16% (Gr) and 1.54% (PI). The arborescent and understory layers showed a common floristic procession (Index of Jaccard) of 36.36% in mature forests established on Gr and 25.61% in mature forests established on PI. The effect of trees' basal area and substrate (explained variance: 69.26%, RDA1: 85.46%, RDA2: 4.56%) on the understory layer's spatial organization was also observed.

Keywords : *Basal area, substrate, regeneration, Rubi Tele*

Résumé

L'objectif de la présente étude vise à analyser l'effet de la surface terrière des arbres et du substrat sur la régénération des forêts matures du Domaine de Chasse de Rubi Tele. Situé dans la partie Nord-Est de la République Démocratique du Congo (RDC), ce domaine chevauche les provinces de la Tshopo et du Bas-Uélé. Un recensement de tous les arbustes et les arbres présentant au moins 1 cm de diamètre a été réalisé dans vingt (20) parcelles de 0,05 ha (100 m x 5 m) chacun. Le cumul simultané de superficie a illustré l'apparition de 95 espèces (2195 individus) dans la forêt mature établie sur sol Périodiquement Inondé (PI) et 82 espèces (3192 individus) dans celle établie sur terre ferme graveleuse (Gr). Le taux moyen de recouvrement basal des arbres par rapport à la surface d'inventaire (0.05 ha) de chaque relevé était de 2,16 % (Gr) et de 1,54 % (PI). Les strates arborescente et arbustive présentaient un cortège floristique commun de l'ordre de 36,36 % (Gr) et de 25,61 % (PI). L'effet de la surface terrière des arbres et du substrat (variance expliquée : 69,26 % ; RDA1 : 85,46 % ; RDA2 : 4,56 %) sur la flore arbustive a aussi été constaté.

Mots clés : *Surface terrière, substrat, régénération, Rubi Tele*

1. Introduction

The forest regeneration depends on tree spatial organization and the substrate on which it is established. It is the result regeneration is the result of dispersal, seed germination and seedling survival in correlation with the distribution of main trees (Fajardo et al., 2006). This correlation can, in turn, be affected by disturbances (Nathan and Muller-Landau 2000).

At small scales, these disturbances in the case of gap determine regeneration zone (Brokaw, 1987; Denslow, 1987; Hubbell and Foster, 1986; Oldernan, 1983; Denslow, 1980). Authors such as Pascal (1995), Durrieu de Madron (1993) and Loffeier (1989) also showed that the death of trees (emergent, dominant and dominated trees) on feet gave the possibility to diaspores to grow and to heliophilous and pioneer species present in the understory layer to settle.

Beyond the effect of tree structure, it was reported that habitat heterogeneity conditioned the distribution of tree species seedlings and regenerations (Ter Steege et al., 2000). In addition, this heterogeneity reflects strong behavioral differences in relation with the expression of the ecophysiological, morphological and demographic characteristics of each species on the one hand, and the development of each individual on the other hand (Costa, 2004).

The establishment of the Rubi Tele Domaine de Chasse mature forests on dry gravelly soil (Gr) and on Periodically Flooded soil (PI) offers to us the opportunity to analyze the effect of trees' basal area and of the substrate on the regeneration in this part of the DRC. We assumed that, by controlling some ecosystem processes, the structure and the diversity of the understory layer could differ from one forest type to another. Comparing the composition of the understory layer in relation with that of the arborescent layer between forest types could allow the identification of the threshold in the relationship existing between these two layers. Due to the influence of the composition and density of the tree cover on some ecosystem processes such as nutrient cycling and light transmission, we assumed that the trees' basal area and the substrate would create conditions that favor the development of understory layers species in RTDC mature forests.

2. Material and Methods

2.1. Study area

Created since 1930 (51th legislative Ordonnance / Agri.; 12th december 1930), the RTDC is located on south of the Buta city, spanning from 2°32'22.9'' N to 2°43'50.04'' N and 24°38'25.17'' E to 25° 04' 35.98'' E (figure 1). The RTDC straddles the Tshopo and Bas-Uélé provinces in the north-eastern part of the Democratic Republic of the Congo (DRC) where it covers an area of 6 227.74 km² (Iccn, 2012).

The RTDC lays in the Am climatic domain of Vladimir Koppen's classification (1936). Mean monthly temperatures fluctuate around 25°C while annual rainfall varies between 1 500 mm and 1 800 mm / year (Gillain, 1953).

2.2. Data collection

Oriented from East to West, twenty (20) rectangular plots of 0.05 ha (5 m x 100 m) each were installed in mature forests established on Gr (10) and on PI (10). In these plots, all shrubs and trees individuals with 1 cm diameter at least were identified. These inventoried, measured and identified individuals were categorized into two sets where the first set (understory layer) included all shrubs with diameter at the root collar

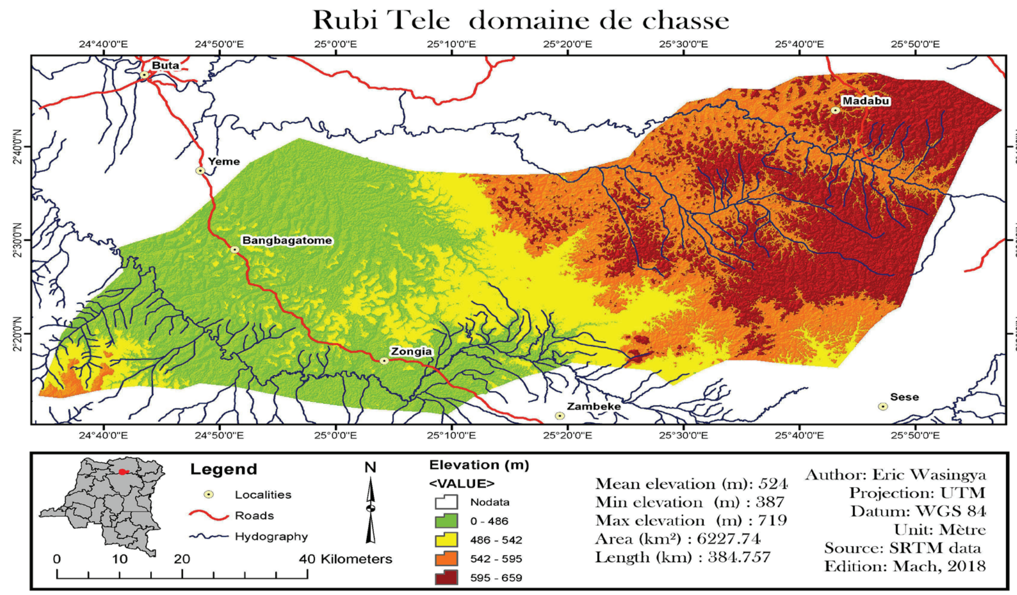

Figure 1 : Map illustrating the Rubi Tele Domaine de Chasse (Katembo et al., 2018a)

(DC) and Diameter at Breast Height (DBH) less than 10 cm (1 cm ≤ DC <10 cm and DBH < 10 cm) while the second set included all trees (arborescent layer) at DBH ≥ 10 cm. Soil samples were collected from the middle of the plot.

2.3. Data analysis

Collected data were used to analyze the floristic composition (species richness, Fisher alpha index and Pielou's Evenness and the structure (density, basal area and above-ground biomass) of the shrub individuals. Characteristic species were determined using the Indval method (De Cáceres, 2013; Dufrêne and Legendre, 1997). The allometric equation was used to estimate the Above-Ground Biomass (AGB) (Chave and al., 2005). The student **t** test was used to compare the floristic and structural parameters between the two forest types (Gr and PI). The floristic link between the diversity of the arborescent layer and that of the shrub layer was analyzed using the Jaccard similarity index (Jaccard, 1990 in Legendre and Legendre, 1998). The renewal of arborescent layer by the shrub layer was calculated using the natural regeneration index (Rn). The latter was obtained by dividing the number of regenerants by that of trees (Hakizimana et al., 2011; Havyarimana, 2009). If Rn <1, the population is deficient; if Rn ≥1, the population is balanced. The relative frequency and density of species i in each set were calculated. Species with more than 3.5 % of relative density and a relative frequency greater than 40% in the adult component of each woody group were selected as the most representative. The choice of these species, based on this criterion, allowed to check whether they regenerated normally in order to appreciate the capacity of adaptation to the ecological conditions.

The detection of constrained floristic gradients of the trees' basal area, soil (texture, assimilable phosphorus, carbon, nitrogen, pH) and slope has been analyzed using the Redundancy Analysis (RDA).

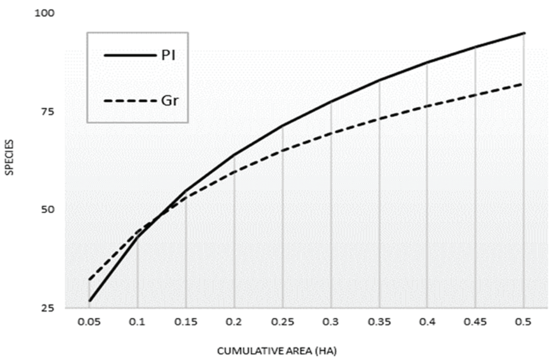

Figure 2: Species-area curves of the understory layer's diversity in RTDC mature forests.

3. Results

3.1. Spatial organization of the flora

The species-area curves (figure 2) illustrated the appearance of 95 species (2 195 shrubs including 45 exclusive species) in the mature forests established on PI and 82 species (3 192 shrubs including 31 exclusive species) in those established on Gr. Comparison of cumulative species values resulted difference in the occurrence of new species (t = 3.094, p = 0.013).

Figure 3 illustrates a higher mean of species richness and Fisher alpha index in the understory layer in mature forests established on Gr (S = 32.3 ± 3.68 species; Fisher alpha = 9.02 ± 1.11) than those established on PI (S = 26.9 ± 7.32 species; Fisher alpha = 8.45 ± 3.43). It was remarked that the situation has reversed for the Pielou's Evenness in RTDC mature forests established on Gr (Pielou's Evenness

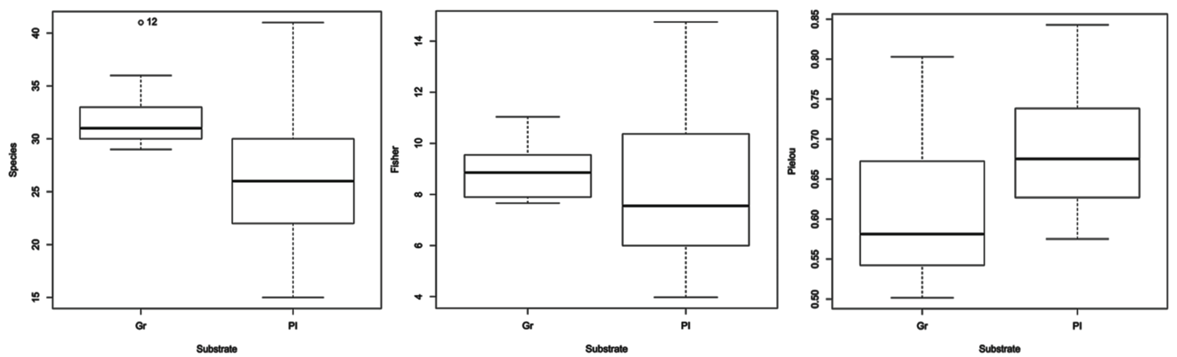

Figure 3: Dispersion of species richness (left), Fisher alpha (middle) and Pielou's Evenness (right) values

= 0.61 ± 0.09) and for those of RTDC mature forests established on PI (Pielou's Evenness = 0.69 ± 0.82) mature forests. The student t test applies to compare the means does not show difference for the species richness (p > 0.05), the Fisher alpha index (p > 0.05) and the Pielou's Evenness (p > 0.05).

The spatial distribution of understory species in the RTDC mature forests illustrated a characterization of *Napoleonaea septentrionalis, Drypetes lisolinoli*, *Diospyros boala* in the RTDC mature forests established on PI and *Cola griseiflora, Diospyros bipendensis, Dialium pachyphyllum* and eleven more for those established on Gr (table 1).

Figure 4 illustrated a higher mean density (D), basal area (G) and estimated Above-Ground Biomass (AGB) in the understory layer of forests established on Gr (D = 6384 ± 1051 individuals. ha^{-1}; G = 6.18 ± 2.05 m². ha^{-1}; AGB = 21.94±8.21 Mg. t^{-1}) than those

Table 1 : List of indicator species characterizing the undergrowth of mature forests considered

Substrate	Species	Probability		Indval	
		Fidelity	**Occurrence**	**Indval**	**p.value**
PF	*Napoleonaea septentrionalis*	0.8851	0.8	0.841	0.037*
	Drypetes lisolinoli	1	0.7	0.837	0.004**
	Diospyros boala	0.6879	1	0.829	0.008**
Gr	*Cola griseiflora*	0.9163	1	0.957	0.001***
	Diospyros bipendensis	0.8734	1	0.935	0.004**
	Dialium pachyphyllum	0.8485	1	0.921	0.002**
	Monodora angolensis	0.7658	1	0.875	0.008**
	Rothmannia libisa	0.9143	0.9	0.907	0.001**
	Hunteria congolana	0.9	0.9	0.9	0.002**
	Leptonychia tokana	0.8947	0.9	0.897	0.005**
	Pancovia harmsiana	0.875	0.9	0.887	0.006**
	Diogoa zenkeri	0.931	0.8	0.863	0.002**
	Rinorea oblongifolia	0.8	0.8	0.8	0.009**
	Angylocalyx pynaertii	0.7872	0.8	0.794	0.023*
	Dasylepis seretii	1	0.7	0.837	0.003**
	Julbernardia seretii	1	0.5	0.707	0.029*
	Napoleonaea imperialis	1	0.5	0.707	0.028*

*Degrees of significance: NS = not significant; significant at the level of *P < 0,05; **P < 0,01; *** P < 0,001*

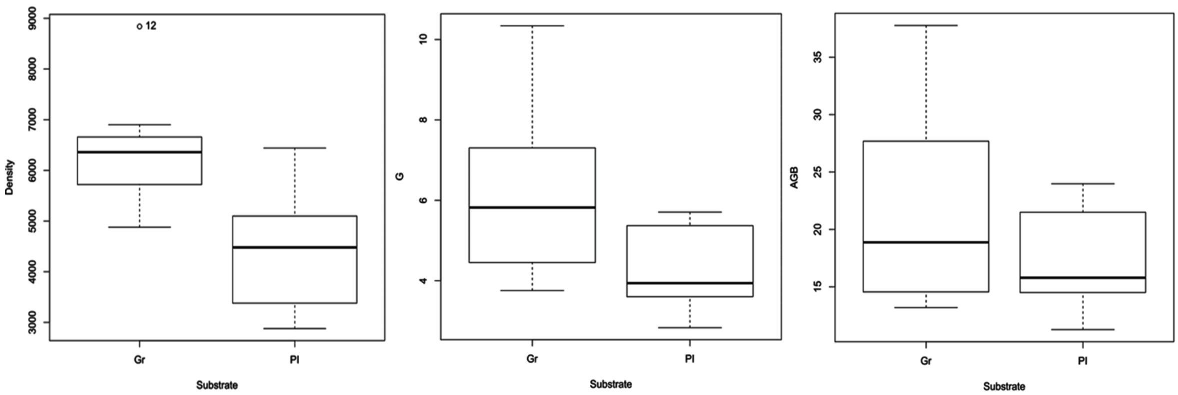

Figure 4: Dispersion per ha of regeneration density (left), basal area (middle) and above-ground biomass (right) values in the RTDC mature forests

established on PI (D = 4390 ± 1080 individuals. ha^{-}; G = 4.24 ± 0.98 m^2. ha^{-1}; AGB = 17.30 ± 4.35 Mg. t^{-1}). The comparison of the density ($p < 0.05$) and basal area ($p < 0.05$) occupied by the regenerators of the targeted mature forests illustrates an effect of substrate whereas it was not the case for the comparison of Above-Ground Biomass ($p > 0.05$).

The mean trees basal recovery rate (figure 5) compared to the inventory area (0.05 ha or 100 m X 5 m) were 2.16% (Gr) and 1.54% (PI). The comparison of these means does not show any difference ($t = -2.093$; $p > 0.05$).

3.2. Floristic affinity and forest dynamic renewal

From the floristic composition present in Gr and PI mature forests, it was found that the understory and arborescent layers presented a common floristic procession of 36.36% (Gr) and 25.61% (PI).

From the relative frequency and abundance of common species to arborescent and understory layers, the finding was that *Gilbertiodendron dewevrei* had the highest numerical potential in juveniles and is followed by *Diospyros boala* (table 2). On the other hand, *Julbernardia seretii, Angylocalyx pynaertii* and *Dasylepis seretii* were abundant and frequent in the arborescent layer of Gr mature forests but poorly regenerated.

The mean regeneration index calculated on the floristic data present in the arborescent layer and present or not in the understory layer in the PI-mature forests (4.83) and in Gr-mature forests (5.88) exceeds unity. This reflects a good regeneration of arborescent layer under its shade.

3.2. Relationship between tested variables and understory layer diversity

The correlation analysis illustrated the effect (explained variance: 69.26%, RDA1: 85.46%, RDA2: 4.56%) of the basal recovery rate of trees and substrate on the undergrowth diversity of the forests considered (figure 6).

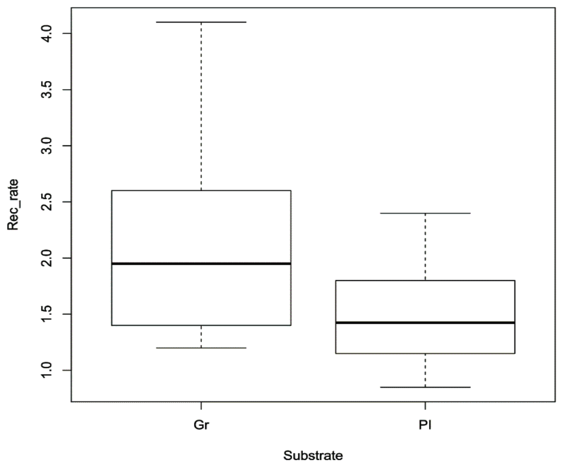

Figure 5: Tree basal recovery rate to the inventory area of Gr and PI mature forests

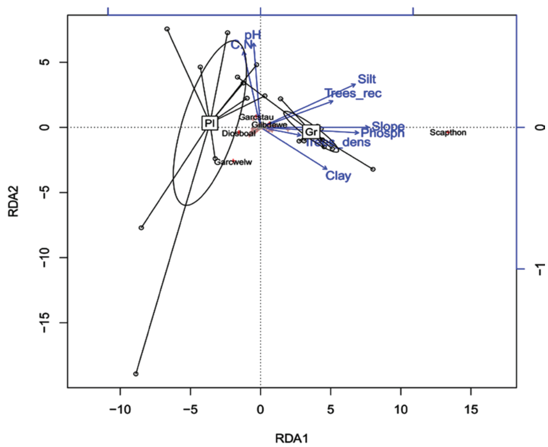

Figure 6. Redundancy analysis illustrating the effect of the arborescent cover rate and of the substrate on understory layer's diversity in the RTDC mature forests

Table 2: Relative frequency and abundance of species dominating arborescent and understory layers

Species	Gr				PI			
	Rel Ab		Rel freq		Rel Ab		Rel freq	
	A&Ad	ar	A&Ad	ar	A&Ad	ar	A&Ad	ar
Gilbertiod. dewevrei	35.51	14.87	90	100	45.61	14.8	80	100
Diospyros boala	6.12	6.15	70	100	8.77	13.9	90	100
Drypetes lisolinoli					4.82	3.73	40	70
Julbernardia seretii	11.02	0.63	90	50				
Angylocalyx pynaertii	7.35	2.32	80	80				
Dasylepis seretii	4.9	0.82	70	70				

4. Discussion

The demographic structure of the understory layer species showed a significant decrease in the number of juveniles as we moved from a lower diameter class to a higher one. This decrease seemed to follow an exponential law. This type is illustrated by massive recruitment of juveniles at the early stage of development (Higgins et al., 2000). In Burkina Faso, Ouédraogo et al. (2006) and Gijsbers et al. (1994) link this decline to drought effects. This statement supports the hypothesis that seedlings are subjected to mortality filters due to predators, pathogens (Augspurger and Kelly, 1984; Janzen, 1970) and heterogeneous light conditions in the shrub (Boyemba, 2011; Baraloto, 2001; Nicotra et al., 1999; Whitmore, 1991). These presumptions do not depart from the observation made in the RTDC mature forests where this decrease is explained by a competition for space, a difficulty of rooting (litter thickness, sandstone slab) and temporary flooding asphyxiating seedlings of some species. The use of the comparison test of means of species richness and alpha diversity between plots (figure 4) showed that all the diaspores in the studied forests had an equal opportunity to grow.

The shrubs floristic composition did not show any noticeable divergences with the DCRT arborescent layer in general whereby Fabaceae, Ebenaceae, Malvaceae, Rubiaceae are present in both understory and arborescent layers. This link can be explained by the fact that the presence of seedlings in a station is mainly favored by the presence of the main plant (de la Mensbruge, 1966) and the external potential (Kimpouni et al., 2013; Dupuy, 1998; Alexandre, 1982).

Structural and microclimatic heterogeneity within tropical forests is one of the causes of the biotope's diversity found there (Tabarant, 2007). This heterogeneity is justified by the canopy cover density which influences diversity and density of the understory layer. This finding is similar to the results found in RTDC mature forests where the understory density correlates positively with the rate of basal tree cover (figure 7). The sparse canopy correlated with the high local diversity (Fisher alpha) of the understory layer can

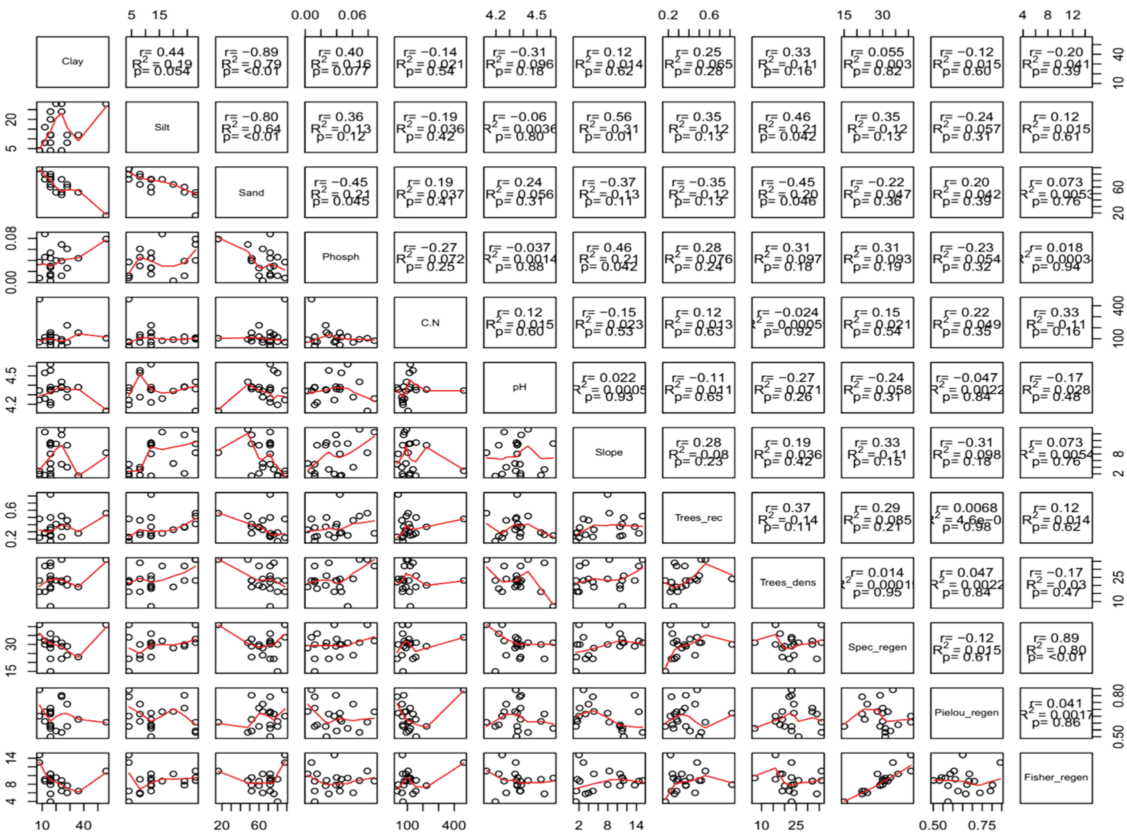

Figure 7: Relationship between basal tree cover, topo-edaphic variables and those (diversity and structure) of regeneration

be explained by the penetration of light rays favoring the development of most heliophilous species. This finding was also made in forests with Pericopsis elata (Boyemba, 2011) and in *Gilbertiodendron dewevrei* PI-mature forests (Katembo, 2013). An attention was also drawn to the nature of the substrate where Djago and Sinsin (2005) found that soil geomorphology had an effect on local undergrowth diversity. This effect was found in the mature forests established on the RTDC where regeneration conditions were difficult.

Raolinandrasana (1996) assumes that these conditions are the result of the sandy soil texture combined with the structure of that forest. Additionally, the seedlings that come to settle face the problem of periodic flooding. This flood creates a congestion phenomenon and eliminates seedlings by asphyxiation. Moreover, the conditions of installation of the regenerators on the dry soil are sufficient except that they meet poor light conditions which hinder the development of the seedlings. This finding is similar to the results found by Sabongo (2015) in *Gilbertiodendron dewevrei* monodominant forests.

5. Conclusion

The appreciation of the species richness and demographic structure of the understory layer revealed an unequal distribution of individuals between species and estimated Above-Ground Biomass. A distribution that is justified by a mesological heterogeneity and the density of the canopy. This heterogeneity did not influence the species richness, local diversity, density and basal area of the undergrowth. It should also be noted that the floristic trend of species in the arborescent layer is also reflected in the understory layer. This is illustrated by a strong floristic dependence between these two components of vegetation.

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