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INFLUENCE OF PROXIMITY OF HUMAN SETTLEMENTS ON THE FLORA AND VEGETATION IN THE PERIPHERY OF THE BIOSPHERE RESERVE NIOKOLO- KOBA IN SENEGAL

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Abstract: Biosphere Reserves are areas of *in situ* conservation of biodiversity. They are subdivided into a central area, buffer zones and peripheral areas. People settled into villages around the periphery of the Biosphere Reserve of Niokolo Koba. The socio-economic activities of those rural populations are largely dominated by agriculture and pastoralism. Business of forest products and to a lesser extent tourism, are also observed. Other forms of activities such as beekeeping, fishing and hunting are practiced. A stratified random sampling technique was used to collect data on diversity and actual trends in population dynamic of woody plant species under the pressure of human activities. The number of woody plant species decreased from far away vegetation's layers to those next to human settlements. The shrub savannah is the most represented vegetation unit but patches of degraded forest galleries were also identified. The woody plant species of the biosphere reserve could be grouped into four categories with respect to their economic importance. Species exploited for firewood and charcoal have a generally viable population with a tendency to domination by Combretum species known as "Combretinisation" in the entire area. Species exploited for timber products are scattered throughout the area and show unbalanced populations. Plant species exploited for non-timber forest products showed a declining population. Timber business, forest clearing for agriculture, bushfires and the exploitation of non-timber forest products are the main factors causing the degradation of plant resources.
Keywords: biodiversity of woody plants, flora, vegetation, Biosphere Reserve Niokolo Koba, peripheral zone.

Introduction

In Senegal, efforts toward conservation of biodiversity were translated into creation of national parks, some of which turned to be Biosphere Reserves. The National Park Niokolo-Koba was created to preserve animal and plant biodiversity as well as local ecosystems (Diouf and Fall, 2001). It became a Biosphere Reserve included in the "World Heritage"

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since 1981. The Biosphere Reserve Niokolo-Koba (BRNK) is located in southeastern Senegal between 12°40 'and 13° north latitude and 20'de 12 ° 30' and 13 ° 20 'west longitude. Like all Biosphere Reserves, the BRNK is divided into three functionally complementary areas that are the central area corresponding to the Park, the buffer zone and the periphery. The central area and the buffer zone are under the responsibility of the Authority of National Parks. The natural resources of these areas are banned from all forms of exploitations except for scientific purposes. Visitors are allowed to enter the park for educational or cultural reasons.

The periphery in contrast houses villages and lands managed by local communities (IUCN, 2006). Village territories are lands under the responsibility of local communities aimed to support their livelihoods. All natural resources in these territories are prone to any form of exploitation for domestic use or to generate income. The land can be exploited for pasture, agriculture, housing, etc. Commercial exploitation of natural plant resources from these territories is however subjected to a permit from the Water and Forests Authority. Therefore, beside anthropogenic pressure, many natural factors contribute to the degradation of natural plant resources in this area in particular. Droughts, bushfires and increasing social demand for forest products lead to an acceleration of the conversion of forests to agricultural land (Pafs, 1993). The impact of these factors varies according to climate, production systems and policies for the conservation and management of ecosystems.

In the Biosphere Reserve of Niokolo- Koba, the landscape is rather flat, but becomes increasingly uneven toward the southeast, where many hills are located (Ba et al., 1997). Three major geomorphological features such as plateaus, valleys and hills were distinguished by Michel (1971). The tropical Sudanese climate is characterized by a long dry season of seven months and a relatively short wet period of 5 months (Leroux, 1983). The average monthly minimum and maximum temperatures for the data set of 1950 - 2005 at the Station of Tambacounda are 18 °C for the coldest month (December) and 40 °C for the warmest month (April). The average annual temperature is 29 °C. The flora is diverse in relation with to the diversity of ecosystems. Adam (1966) and Schneider and Sambou (1982) estimated the list of flowering plants species to over 1,500, representing more than 62% of phanerogams from Senegal. Ba et al. (1997) reported 1117 plant species belonging to 120 families from BRNK, with the Poaceae, Fabaceae, Cyperaceae and Rubiaceae families representing the most important. Many studies including those of Schneider and Sambou (1982); Madsen et al, (1996); Ba et al, (1997) and Traoré (1997) reported that the BRNK is composed of two major types of vegetation that are savannas and forests. They mentioned also the existence of

two particular vegetation groups composed with Palmyra palm and bamboo forests. The periphery of the Biosphere Reserve Niokolo- Koba is characterized by human settlements of great ethnic, sociological and linguistic diversity. The main ethnic groups are the Fulani, the Bassaris, the Bédiks, the Diakhankés and the Mandingo. Agriculture under rainfed conditions is the main activity covering most arable lands. Irrigation is practiced in the valley of the River Gambia and focuses on banana production (PROGEDE, 2002). The livestock sector gives business for about 25% of people in the periphery because of the high potential in pastoral resources. Animals are taken during the rainy season mainly in classified forests because fallows are rather rare around the villages. In addition to agriculture and livestock, people exploit forest resources to improve their living conditions and incomes. The exploitation of wood products for common purposes (firewood, timber, fiber extraction, pruning and harvesting fodder trees) is very common. Palmyra palm and bamboo are exploited for housing and decorations. This work was undertaken to look at the actual state of biodiversity and dynamics of populations of woody plant populations of the peripheral zone of the Biosphere Reserve Niokolo- Koba.

II. Methodological Approach

Developing the map of the sampling area

The rate of ground coverage by the canopy of trees and shrubs was used. A Landsat ETM + image of October 9th, 2001 with a spectral resolution of 30 m above ground, was used. The image was chosen at that date (end of rainy season) to avoid hand interference of chlorophyll activities due to herbaceous plants, but also disturbances related to cloud cover. Image processing was performed with the Chips Win 4.5 program. The resulting map showed different classes discriminated by the coverage of tree and shrubs canopy called strata (Figure 1).

A stratified random sampling was used to collect data on flora and vegetation in the periphery of the Biosphere Reserve of Niokolo- Koba. The procedure consisted into dividing the study area into homogeneous plant community strata in terms of ground coverage. Two draws were thereafter conducted. The first draw was made within different strata in order to determine the sampling locations (primary units) and a second draw, within the sampling sites, allowed selecting the sample units (secondary units). The implementation of this procedure required a map of the site.

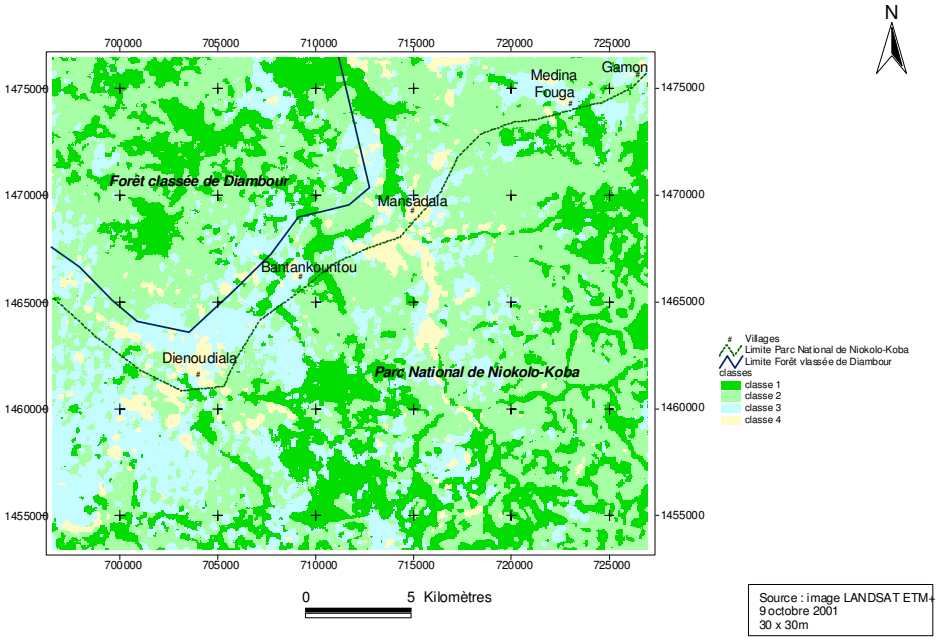

Figure 1: map of study zone in the periphery of BRNK showing different classes discriminated by the coverage of tree and shrubs canopy.

Collecting data on the flora and vegetation

The discriminated strata were subdivided into square of 200 m x 200 m, corresponding to sampling sites. Only sampling sites entirely included in the strata were considered. A number was assigned to each potential sampling site, and a draw without replacement was used to identify the actual sampling sites. Another draw within the sampling site was conducted to locate the sampling unit of 20 m x 20 m. In each sampling site, eight directions departing from the center were chosen (Figure 2). For each direction, a draw allowed to locate one of the potential 5 sampling units for the inventory. In each sampling unit, all woody plant species were counted and identified. The diameter at breast height (1.30 m high) and the total height of the trees and shrubs were measured.

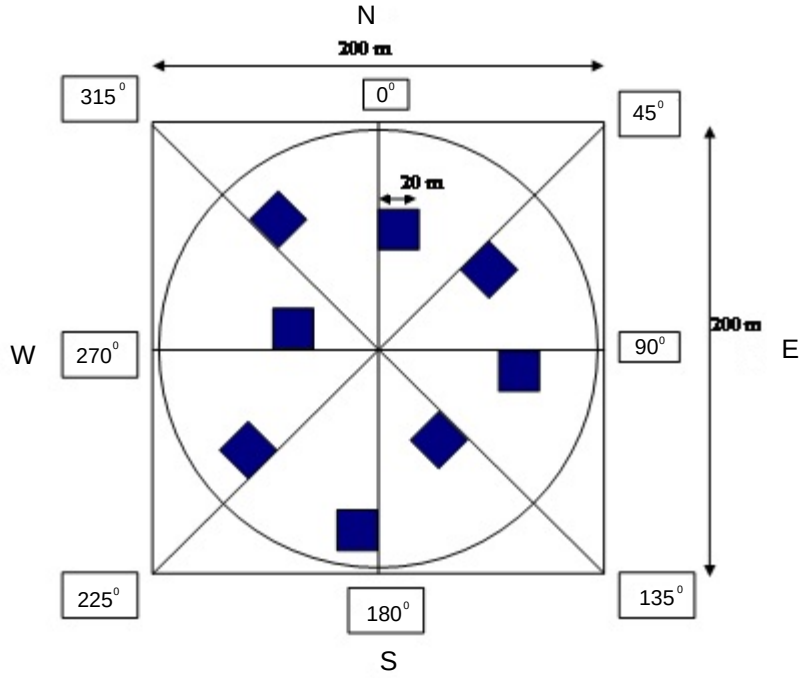

Figure 2: scheme of sampling site showing the eight directions departing from the center and examples of sampling unit identified in those directions

Categorizing woody species according to uses

Woody plant species were grouped into classes according to their uses identified different classes (Von Maydell, 1991; Arbonnier, 2002 and Sambou, 2004). Trees and shrubs were ranged into groups by considering the most common form of use. Different groups of species were therefore identified. Woody plant resources are exploited for fuelwood and charcoal, timber and non-timber products. There are also woody plant species of none or weak exploitation.

Data analysis

An analysis of variance was performed for data with a normal distribution. Data expressed in percentage were first normalized by arcsinus transformation. The statistical analysis software Minitab 13th edition for Windows was used. Means were separated using the Student test & Newman Keuls at 5 %.

RESULTS

Ground occupation

The analysis of the satellite image allowed discriminating land units or strata. Human settlements and agricultural zones represented stratum 4. It was therefore not considered for the study. The 3 other strata were made of vegetation types discriminated by the rate of ground coverage by the canopy of trees and shrubs. Stratum 3 surrounded the villages while

stratum 2 was away from houses. Stratum 1 consisted of pieces of land depressions sometimes next to villages. The surface covered by the different strata is variable (Table 1). Stratum 3 alone occupied over 45% of the total area, followed by strata 2, 1 and 4 respectively. The number of sampling units studied gave 24 relevés for stratum 1, 40 relevés for stratum 2 and 64 for stratum 3.

Table 1: Characteristics of the study area and sample size

Stratum	Surface (ha)	Relative importance (%)	Number of total sampling sites	Number of sampled sites (400 m x 400 m plots)	Number of sampling units (20 m x 20 m plots) studied
1	1055,92	14,70	70	3	24
2	2835,69	28,75	108	5	40
3	4500,90	45,64	163	8	64
4	1168,7	10,89			

Woody plant flora

A total of 86 woody plant species including 65 in stratum 1, 63 in stratum 2 and 56 in stratum 3 were identified. These species belong to 68 genera and 30 families. The most diverse families are the Combretaceae (12 species), Caesalpiniaceae (10 species), Mimosaceae (9 species), Rubiaceae (8 species), Fabaceae (7 species) and Anacardiaceae (5 species). The genus Combretum had the largest number of species (6 species).

Woody plant vegetation

Stratum 1 contained the highest values for most vegetation parameters and stratum 3 the lowest values (Table 2). Stratum 1 had a rate of ground coverage by tree canopies over 57% and an average density of 260 individuals / ha. In this stratum, a density of 134 trees / ha and 126 shrubs / ha was recorded. The average diameter of trees and shrubs was 22,41 cm and 10.83 cm respectively, with an average diameter of all the individuals of 16.76 cm. Shrub species (*Combretum glutinosum*) and two tree species (*Pterocarpus erinaceus* and *Daniellia oliveri*) were the dominant species. This stratum lies in a depression and represents a forest gallery with regressive dynamics (Adam, 1966).

In stratum; 32.81% of ground surface was covered by the canopy of trees and shrubs. A tree density of 50 individuals / ha and 187 shrubs / ha were found. These trees and shrubs had a

mean diameter of 23.83 cm and 11.31 cm respectively. *Combretum glutinosum*, *Hexalobus monopetalus* (shrubs) and *Pterocarpus erinaceus* (tree species) were the dominant species. This stratum corresponds to woodland. In stratum 3, only 20.44% of ground surface was covered by the canopy of woody plant species. The average density woody plant species was 162.39 individuals / ha, with shrubs species representing about 78% of this stratum. The average diameter of trees and shrubs is respectively 20 cm and 9 cm. *Combretum glutinosum* was dominant in this stratum, corresponding to a bushland.

Table 2: parameters of vegetation of the 3 strata in the periphery of Biosphere reserve Niokolo-koba. In the same line, numbers followed by different letters are significatvely different at $p \leq 0.05$.

Parameters of vegetation	**Stratum 1**	**Stratum 2**	**Stratum 3**
Ground coverage (%)	57,81a	32,81b	20,44c
Density of trees (ind / ha)	134,37a	50,00b	52,77b
Density of shrubs (ind / ha)	126,56a	187,50a	109,37b
Total density (ind / ha)	260,06a	237,10ab	162,39c
Tree height (m)	9,29a	9,03a	8,33b
Shrub height (m)	5,60 a	4,97 a	4,84a
Mean height of woody plants (m)	7 ,76 a	6,26 b	5,05b
Tree diameter at 1.30 m (cm)	22,41a	23,83a	20,19b
Shrub diameter at 1.30 m (cm)	10,83	11,31	9,34
Woody plant diameter at 1.30 m (cm)	16,76a	15,16a	13,40b

Population trends of woody plant species exploited for firewood and charcoal

The woody plant species exploited for firewood and charcoal encountered in the peripheral zone of the BRNK had a regular distribution of individuals in their diameter classes (Figure 3). Among the 7 species listed, *Combretum glutinosum* had a remarkably regular distribution of individuals in the different diameter classes, but also large populations. *Terminalia macroptera*, *Terminalia avicennoides*, *Terminalia laxiflora* and *Combretum nigricans* had also a regular distribution of their populations in the diameter classes but low numbers of individuals.

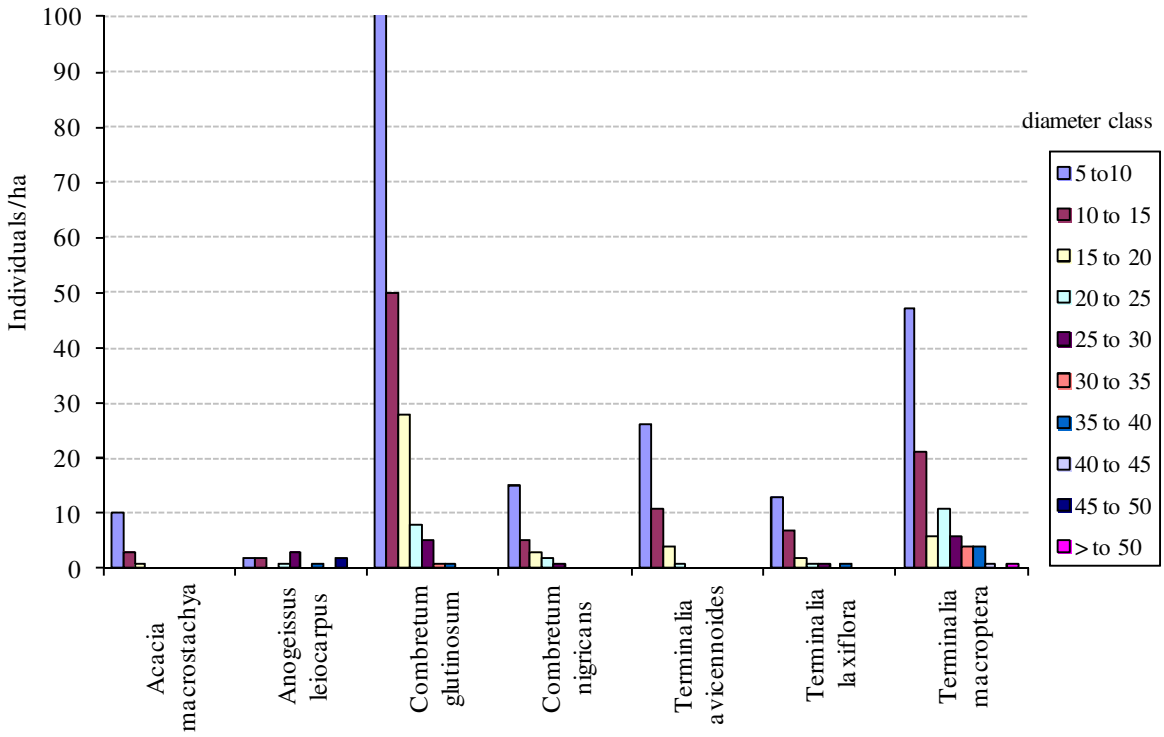

Figure 3: Distribution of populations of woody plant species exploited for firewood and charcoal from the peripheral zone of the BRNK in different stem diameter class

Population trends of woody plant species exploited for timber

Populations of plant species exploited for timber are relatively small and their structures difficult to assess (Figure 5). Among the 7 species recorded, *Pterocarpus erinaceus* was the only species with a relatively large population size. However, individuals of this species were distributed irregularly in diameter classes. Other species like *Prosopis africana* or *Khaya senegalensis* had very low numbers of individuals, varying sometimes between 1 to 3 in 1 ha.

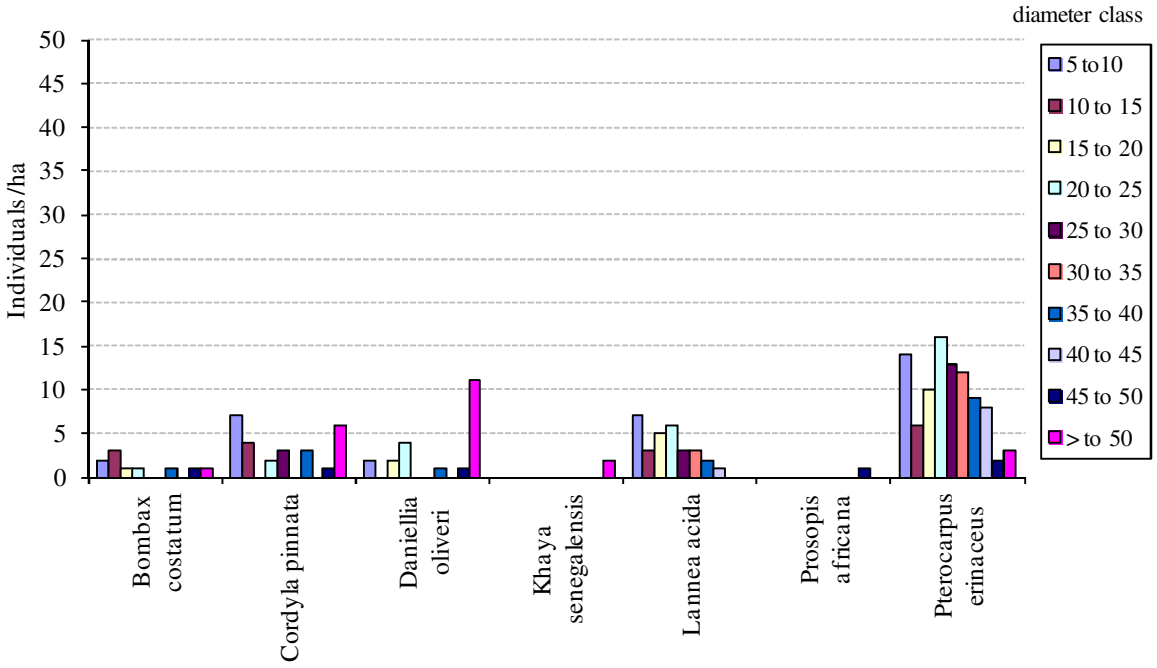

Figure 5. Distribution of populations of woody plant species exploited for timber from the peripheral zone of the BRNK in different stem diameter class

Population trends of woody plant species exploited for non-timber products

This group was represented by 9 species with a small number of individuals that did not allow assessing any dynamic in the population structure (Figure 6). *Vitex madiensis* was the only species to show a population with a fairly good distribution in diameter classes.

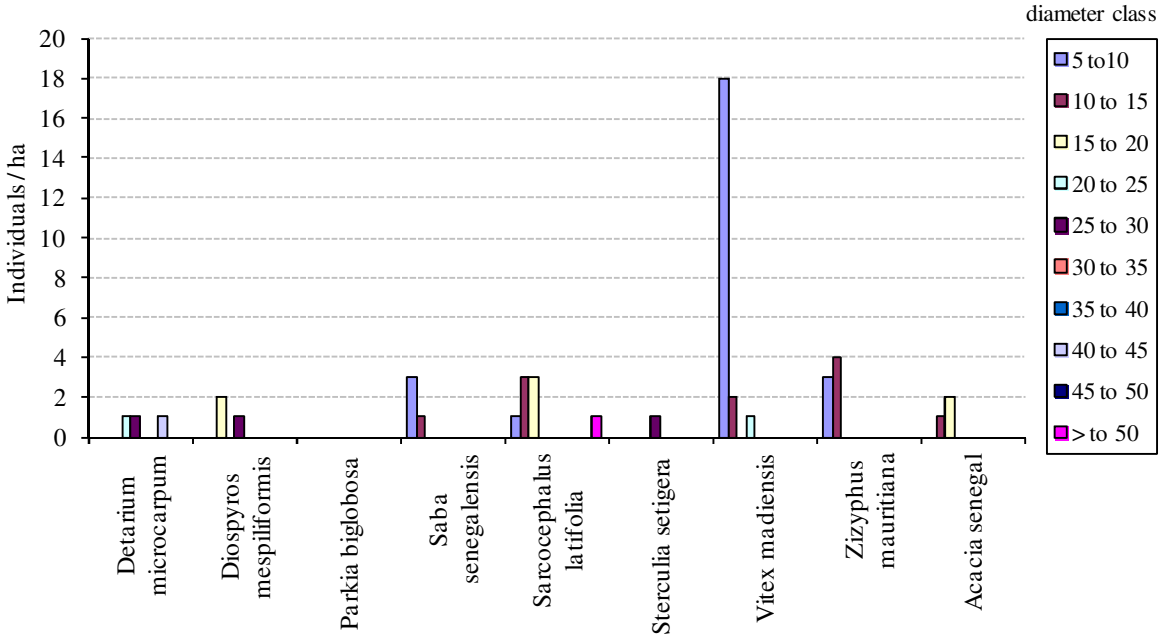

Figure 5: distribution of populations of woody plant species exploited for non timber products from the peripheral zone of the BRNK in different stem diameter class

Population trends of woody plant species with no or little exploitation

The woody plant species with no or little exploitation, with 36 species, were strongly represented in the periphery in different population size. Species such as *Annona senegalensis*, *Combretum crotonoides*, *Dichrostachys cinerea*, *Hexalobus monopetalus*, *Strychnos spinosa* and *Piliostigma thonningii* had a large population size allowing an analysis for trends in the dynamics of their populations (Figure7). These species had populations with good numbers of individuals spread evenly across the diameter classes.

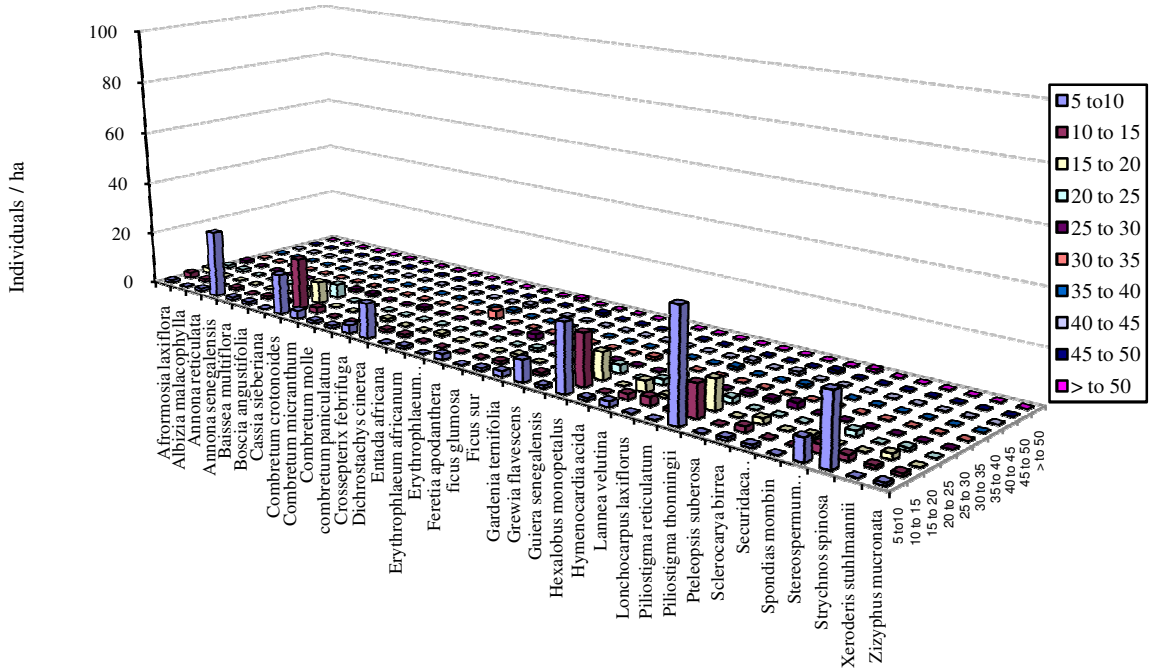

Figure 5: distribution of populations of woody plant species with no or little exploitation from the peripheral zone of the BRNK in different stem diameter class

Discussion

The woody plant flora of the study area was relatively diverse. The most represented plant families are classified as major vascular flora of Senegal (Ba and Noba, 2001). Species of the family Combretaceae are predominant in all Sudano-Sahelian formations, despite their frequent solicitation by rural populations because of their socio-economic. The relevés of flora in strata 2 and 3, respectively the farthest and closest to villages attest for the negative effects of human activities. In fact, the number of species per stratum increased with increasing distance to villages, confirming the negative impact of human pressure on vegetation. Stratum 3, which surrounded the villages, was subjected to more exploitation and recorded the lowest values for the number of species, genera and families. This stratum

hosted also young fallows. Their exploitation several years ago was led for sure to clearing of woody plant species resulting in biodiversity decline (Kperkouma, 2005). Farmers normally suppress spontaneous regeneration in their fields to give space to crops (Ndiaye, 2007). Similar observations were reported in upper Casamance (Diedhiou, 2000).

This seems to reflect the acuity of threats to the environment of the BRNK related to population growth in its immediate vicinity. Migration of populations towards the periphery of the BRNK resulted in colonization of forest lands in the vicinity of the Niokolo Koba Park (Diallo, 2005). A continuation of this trend would extend the facies of stratum 3 to more forest areas. The vegetation of the study area consisted of savannas (woodlands and shrublands). Bushlands were also strongly represented. This strong representation reflects the increase in areas cleared for agriculture. These savannas are considered ancient landscape reshaped by man (Schnell, 1976). They are anthropogenic savannas that settled in favor of management fires and human activities (Louppe et al., 1996). Scraps of gallery forests located in small valleys are observed, but still degrade due to adverse climatic conditions and human activities.

Woody plant resources of the periphery of the Biosphere Reserve Niokolo- Koba are used for multiple purposes like domestic energy, timber and non-timber forest products. Plant species exploited for fuelwood and charcoal account for 47% of the total woody plant biodiversity. But this greater representation in numbers hides the low population size of many of these species. Only *Combretum glutinosum* had high numbers of individuals. Its population is viable and able to recover. This species is known to be less affected by bushfires and drought (Traoré, 1997 and Sonko, 2000). It also has a high shooting rate after cutting ofr burns, in addition to its young individuals being less preferred by the livestock (Sambou, 2004). As a consequence, a process of "combretinisation", meaning a large domination of plant population by *Combretum glutinosum* in the peripheral zone of the BRNK is under progress. To state, nearly half of the populations at all stages of development was represented by *Combretum glutinosum*. For plant species exploited for timber, low populations were present. The exploitation of adult individuals and the pressure linked to cattle grazing of younger individuals could be responsible for the low densities (Sambou, 2004). Their populations showed signs of disturbance because of big specimens targeted for exploitation (Akpo, 1993). Population size for woody plant species exploited for non-timber products are very low. The number of individuals was rather small and difficult to assess for any trend in the population structure. Because of over-exploitation of their products, species

of this group presented unbalanced populations (Ndiaye, 2007 and Peters, 1997). The largest number of species was observed in the category of not exploited plants or plants with low socio-economic value. They had however low numbers of individuals. These species, mainly represented by shrubs, were dominated in terms of number of individuals, by *Hexolobus monopetalus* and *Strychnos spinosa*. Most of them had a constantly renewing population and were therefore viable in the absence of major disruption. The flora and vegetation of the periphery of the Biosphere Reserve Niokolo- Koba are in addition to climate variations, subjected to human activities leading to their degradation and threatening the viability of their populations. They are affected by a number of factors such as land clearing, cutting for wood, grazing by livestock and exploitation of non-timber forest products. To balance the negative impact of these factors, the implementation of a number of measures would allow a rational and sustainable use of natural resources and biodiversity. Measures consisting with the establishment of community nature reserves, ownership of the charcoal making business by local populations, and a better marketing of non woody forest products, could help preserve the nature resources in the periphery. The revitalization of agroforestry with the use of species of high economic value could also allow reducing the pressure on natural plant resources while increasing income of the rural populations.

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