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The evolution state, compositional and structural diversity of ecosystems in restoration in the Sudano - Sahelian zone of Cameroon

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Abstract

Natural resource management has become a major concern in scientific debates. In order to understand the evolution of the vegetation, a study was done on the evolution state, compositional and structural diversity of ecosystems in restoration in the Sudano-Sahelian zone of Cameroon. The circular method with the two-compartment circular plots (A and B) was used for woody inventories. In compartment A of radius R = 20 m and 0.1256 ha of area, all trees of dhp ≥ 5 cm were measured. In compartment B with a radius of 5 m and an area of 0.00788 ha and circumscribed in compartment A, saplings and juveniles (dhp <5 cm) were counted. The results showed that vegetation of department of Mayo-kani and the Diamaré are dominated by the red color before installation of green sahel. These two departments were strongly degraded. This degradation is due either to the different human activities or to the effects of climate variation. The departments of Mayo-danay and Mayo-sava witch the vegetation presented the green color is dominated by shrub and tree savannas. After reforestation, the department of Mayo-kaniis dominated by green color. These changes could be explained by the defending of these areas since after the installation of the sites certain decisions were made by the initiators of the project as well as the local population to promote the success of these protected areas. These decisions include the ban on green logging, the ban on hunting, the practice of agriculture and many others. It is true that these areas are still under anthropic threat but it is clandestine. A total of 89 species were identified divided into 58 types, 26 families and 7222978 individuals. The family Caesalpiniaceae, Mimosaseae and Combretaceae are the most widespread in the sites. As for the species *Balanites aegyptiaca* and *Acacia nilotica* with a percentage of 87.3% appear in the 79 records out of 86 so they were the most abundant. According to the height and diameter the species have "L" structure. The juvenile's species are more abundant and dominantin Green Sahel vegetation.

Keywords: Evolution state, phytodiversity, Green Sahel, Far-north.

Introduction

Awareness of serious environmental damage such as the frequency of extreme weather events, the false start of the rainy seasons, the recent floods, the recurring droughts that the world is increasingly facing, prove that climate change has ceased to be a strictly scientific issue of a distant future of the planet, becoming a real and pervasive problem for everyone (MINEPDED, 2014). It is relatively recent, and starts from the 1972 Stockholm Conference in Sweden called the United Nations Conference on the Environment (UNCED) which adopted a set of principles for environmentally sound environmental management under the name of "Stockholm Declaration" (Amougou, 2011). The Stockholm Declaration placed environmental issues high on the international agenda and marked the beginning of a dialogue between industrialized and developing countries on the link between economic growth, pollution of the global undivided (the air, water, oceans) and the well-being of people around the world (MINEPDED, 2014).

Subsequently, the Rio de Janeiro (Brazil) Conference in 1992 called the United Nations Conference on Environment and Development (UNCED) adopted a Declaration that advanced the concept of the rights and responsibilities of countries in the field of the environment. This conference, held under the theme: "The Future We Want," emphasized on the importance of the social, economic and environmental benefits of resources for people.

Later, the Johannesburg Conference held 10 years after the Rio Conference, emphasized on the protection of the environment and socio economic development as fundamental base to sustainable development, based on the Rio principles. For example, the global Agenda 21 and the Rio Declaration on Environment and Development were adopted.

At the end of the Rio conference, the government of Cameroon developed and implemented policies and strategies built on the principles of sustainable development and created within its ministerial department in charge of environmental issues, a division in charge sustainable development component (MINEPDED, 2013). Thus, the management of the environment in Cameroon is governed by the law n ° 96/12 of 05 August 1995 on a framework law relative to the management of the environment. Published on August 05 in 1996, it governs all environmental management in Cameroon. It is in this context that it has ratified the United Nations Conventions related to the environment including the United Nations Convention to Combat Desertification. In accordance with the provisions of this Convention, Cameroon has drawn up and adopted its National Plan of Action to Combat Desertification (NAP / LCD) in 2006. The implementation is materialized by several sustainable land management initiatives throughout the country particularly the Green Sahel operation (MINEPDED, 2013). This commitment of the Cameroonian government materialized in the wake of the great drought that hit the Sahelian countries and the northern part of Cameroon in the 1970s, Cameroon, like the other states of the sub-region located in Cameroon. The edge of the Sahara is decided to implement activities to fight against drought. One of the major enterprises will be the creation of the Provincial Committee for Drought Control (CPLS) in response to the Sahel countries which had gathered around the Inter-State Committee for Drought Control in the Sahel (CILSS) which had then closed their doors in Cameroon.

The "Green Sahel" operation was entrusted to the Ministry of Youth and Sports, which was already overseeing other civic training activities for young people in fields such as agriculture and small trades between 1970 and 1980. Unfortunately, this project stopped for reasons such as lack of funding; poor mastery of basic forestry techniques (quality and type of plants, lack of study on soils, size of holes in plantations) and control of water; the lack of involvement of local populations; failure to put in place a post-planting monitoring framework. All of this led to the disinterestedness of population, which did not feel at all responsible or concerned. Then with the adoption of the PAN LCD in 2006, the Green Sahel operation was launched against in 2008 under the authority of the Ministry of Environment, Nature Protection and Sustainable Development (MINEPDED) in the far-North region of Cameroon with the main objective of restoring degraded lands in areas affected by desertification by effectively combating land degradation and increasing soil fertility. It was also aimed at reversing the trends of desertification / land degradation, through actions that improve the living environment and production bases for the populations and strengthen the dialogue and complementarily around the actions to fight desertification process and sustainable management of natural resources. According to Fotsing (2009), the far north region of Cameroon is an example of a dry savannah region of Central Africa that faces the challenge of the population explosion. The increase of population causes pressures on natural resources to meet social and economic demands. There is a decline in woodlands areas which in 20 years have gone from 29.39% of land use to 18.45% around the city of Maroua. This decrease is attributed firstly to the over logging of woody species to meet the growing needs of the population following a population explosion that increased from 1855678 inhabitants in 1998 to 3.111 792 inhabitants for the Far North region at the third census in 2005 (INSC, 2010), following the conquest of arable land and pastures. Through this practice, born the concept of lands the change of use which today is at the origin of the disappearance of the numerous vegetable formations in favor of agriculture whose estimated value is of the order of 60% / year (FAO, 1997). To these difficulties, would be added the lack of knowledge of framework environment law in 1996, the application text of Cameroon forests code and all the texts governing the activities of this nature. The factual problem facing this part of Cameroon is the pressure on lands and natural resources, whether for subsistence needs, firewood, grazing or logging. Despite its rich potential, the desertification phenomenon and land degradation tends to become widespread and affects all ecosystems, even the most humid because of the increase in population and the destabilization of the area due to "Boko Haram" phenomenon. It is in this context that the present work, which concerns the dynamics and characterization of the phytodiversity of restored ecosystems of the Sudano-Sahelian zone of Cameroon (site of the Green Sahel) and their capacity to reverse the trend of change, is inscribed. In the general framework this study aims to know the state of the ligneous flora which constitutes this zone in order to enable their capacity to answer the needs of the hour and to guarantee those of the future. Generally, it aims to characterize ecosystems of the Green Sahel sites. More precisely to:

- describe the evolution state of the vegetation cover of the study sites;
- study of the compositional and structural diversity of ecosystems in restoration;

Materials and Methods

Study area

The Far North Region is located between 10 ° and 13 ° North latitude and 13 ° East 15 ° East. The region stretches for nearly 325 km, from Sudanese countries to the unlikely shores of Lake Chad. It is limited to the East by Nigeria, to the West by Chad and to the South by the Northern Region (Letouzey R., 1985). Study sites are spread across four departments of Far North Cameroon namely Diamaré, Mayo-Kani and Mayo-Danay and Mayo Sava. The site selection criteria focused on the following aspects: the representativeness of different ecosystems; period of setting up the site. Indeed, for an objective analysis, it was considered appropriate to conduct the study in the not too recent old sites, especially those created at least five years ago, our choices are directed towards sites created in 2009-2010.

For security reasons, this work has mainly focused on the Green Sahel sites of Diamaré, Mayo Danay, Mayo Kani and Mayo Sava. For this purpose, for the present study, four Sahel-green sites were selected (Figure 1).

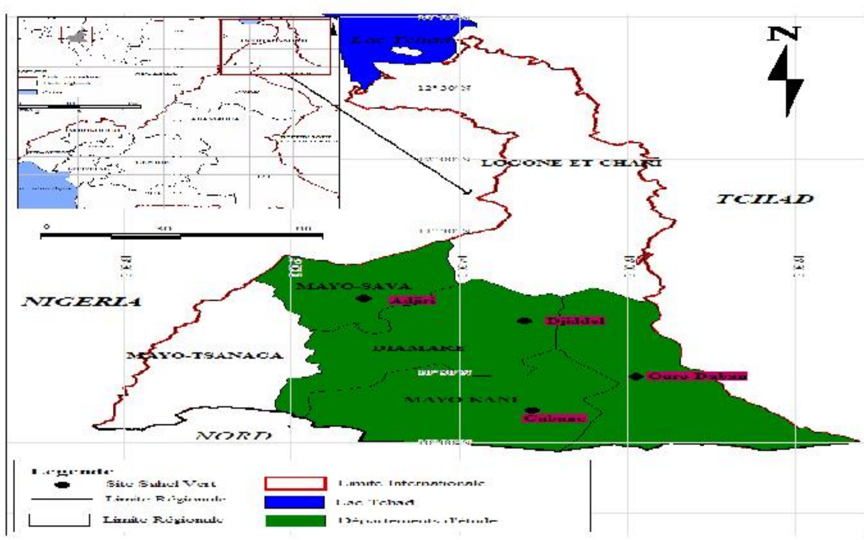

Figure 1: Presentation of the study area

Determination of vegetation evolution by remote sensing

The evolution of vegetation in the area of study was based on the NDVI-VEGETATION (1km) of some types of land use during the period before the establishment of the sites associated with the floristic inventory. The synthesis of these works provides a better understanding of the spatio-temporal evolution of vegetation cover in the far north in general.

Selection and acquisition of satellite images

The period selected for the acquisition of the images corresponds to the dry season especially the months of the beginning of the year that is to say of January and February (Table I). Jensen (1983) recommends this period in studies aimed at detecting observable changes in vegetation. The downloaded images correspond to the MSS (Multi Spectral Scanner), TM (Theematic Mapper), ETM = (Enhance Thematic Mapper) sensors.

Table 1: Acquisition of satellite images

Satellites	Sensors	acquisition periods	Number of bands	Spatial resolution
Landsat3	MSS	February 1982	4	60m
Landsat5	TM	January 1890	7	30m
Landsat7	ETM+	February 2009	8	30m
Landsat8	OLI and TIRS	February 2017	11	30m

Spectral and spatial analysis of vegetation

Spectral analysis distinguishes between different forest types that rely on their structures and their states of degradation (Defries *et al*., 2007, Barima *et al*., 2010)

A set of Operations is required in the processing of our images. Software such as QGIS 2.14, ERDAS 2013, ENVI5. 1 were used. The transformation of images and the extraction of spectral values of vegetation indices were carried out notably by NDVI (Normalized Difference Vegetation Index) defined by TUCKER (1979) and some GDVI (Generalized Difference Vegetation Index) or generalized difference vegetation index. (Statement by Wu, 2014). The formulas for NDVI and GDVI were as follows: NDVI = (PIR-R) / PIR + R) and GDVIn = (SRn-1) / SRn + 1) = (PIRn-R) / (PIRn + R).

Find explanatory parameters

The parameters likely to explain the variation of vegetation indices were realized. It was a factorial analysis approach that was always necessary for understanding ecological phenomena (Ramade, 2009).

Experimental features of vegetation survey sites.

The inventory work took place in two phases. The first phase consisted on surveying of geographical coordinates of the boundaries of each site for the purpose of designing the boundary maps and plot maps. The second phase, for its part, led to the actual inventory work. Random sampling was used as part of this inventory work. Circular plots with two compartments (A and B) were used (Figure 2). The plots are 300 m apart and positioned on the trajectories called transects that are parallel to each other and 250 m apart (Figure 3). In compartment A of radius R = 20 m and 0.1257 ha of area, all trees of DBH ≥ 5 cm were measured. In compartment B with a radius of 5 m and an area of 0.00785 ha and circumscribed in compartment A, saplings and juveniles (dhp <5 cm) could be counted. For each individual, the following protocol was applied: the identification of the species by its scientific name, measuring the circumference at 1.30 m from the ground using a tape measure. All the individuals thus listed have been mapped and positioned in the schematic representation of the plot. We also counted clearings and dead trees on the ground or collected. In a notebook, a serial number is assigned to each individual. On the millimeter grid, the crowns of trees and shrubs were also restored by estimating the ground projection. For this purpose we used the decameter which was also used.

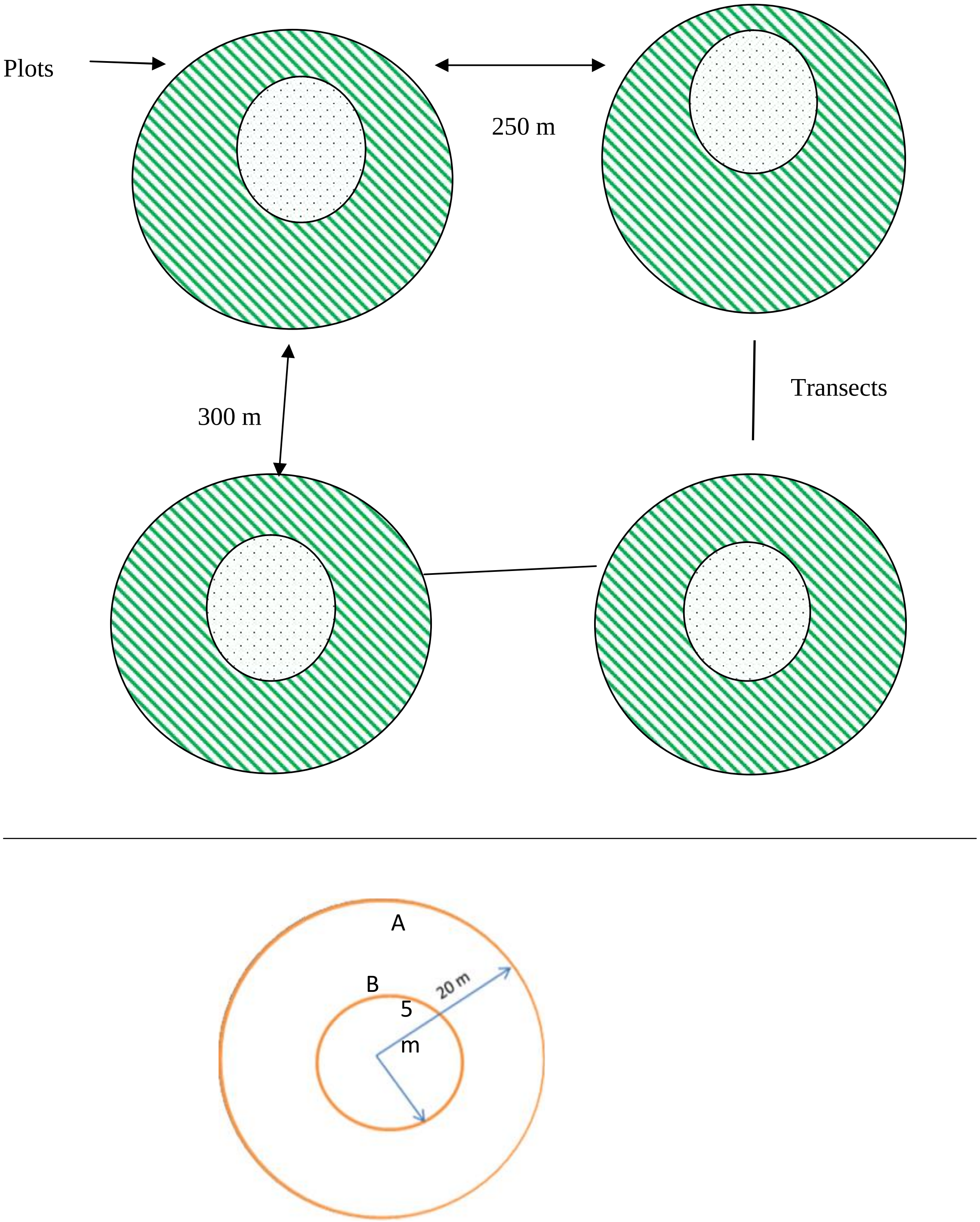

Figure 2: Experimental inventory device

Data analysis

Statgraphic and Excel software are used to analyze the results of the phytomass of shrubs, trees and grasses, Principal Component Analysis (PCA), the on the dendrometric parameters data were analysed. ENVI 4.5 has been used for the processing of satellite images including LANSAT 7 (2009) and LANSAT 8 (2017). QGiS has been used for card layout MAPINFO 8 .5 for the realization of location maps.

Results and Discussion

State of plant cover vegetation before installation of the green Sahel

An overview of the vegetation in the Far North zone showing the state of the vegetation cover before the installation of the green sahel sites is carried out through the NDVI database. This is used as an indirect indicator of the plant cover with two colors red which represents the signs of degradation including bare soil, erosion etc. and the green that represents the vegetation (Figure 3). It appears from this figure that the department of Mayo-kani and the Diamaré are dominated by the red color. These two departments were strongly degraded. As for the departments Mayo-danay and Mayo-sava, the superiority of green color in them which is the index of the vegetation does not absolutely mean that these zones are not affected by the effects of the degradation since the herbaceous carpet which is included in the vegetation. In general, this degradation is due either to the different human activities or to the effects of climate variation. This result is not unlike that obtained by Wilcox and Murphy (1985), which shows that the phenomenon of environmental fragmentation affects almost all regions and its importance has increased as a result of the development of human activities.

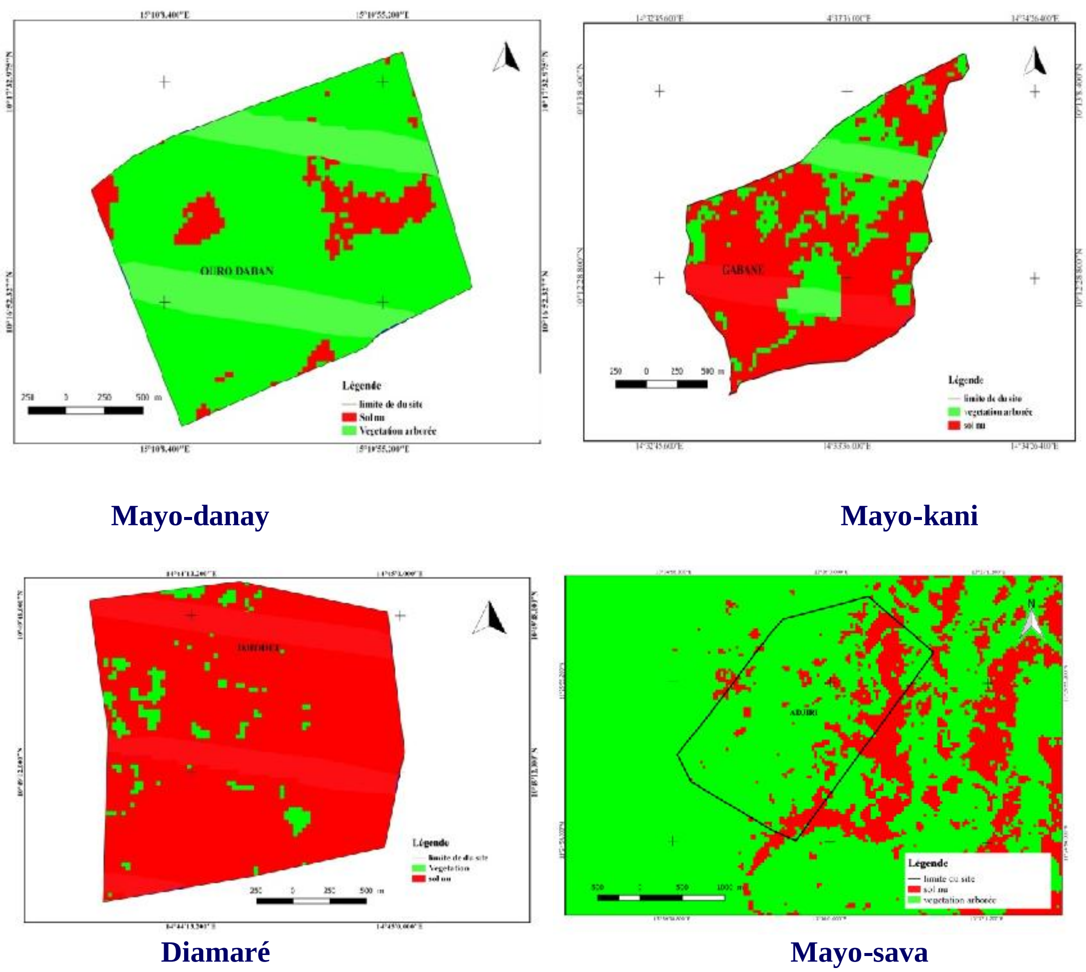

Figure 3: State of plant cover vegetation before installation of the green Sahel

State of the plant cover between 2009 and 2018

Figure 4 presents the state of vegetation cover from 2009 to 2018. This figure shows that vegetation cover at the NDVI database has undergone a slight modification.

The departments of Mayo-kani and Mayo-danay are dominated by the green color. The superiority of green color in them which is the index of the vegetation does mean that these zones are reforested. The reforestation of green Sahel operation made by MINEDED during 2009 and 2018 participate of this dynamic vegetation. These changes could be explained by the defending of these areas since after the installation of the sites certain decisions were made by the initiators of the project as well as the local population to promote the success of these protected areas. These decisions include the ban on green logging, the ban on hunting, the practice of agriculture and many others. It is true that these areas are still under anthropic threat but it is clandestine.

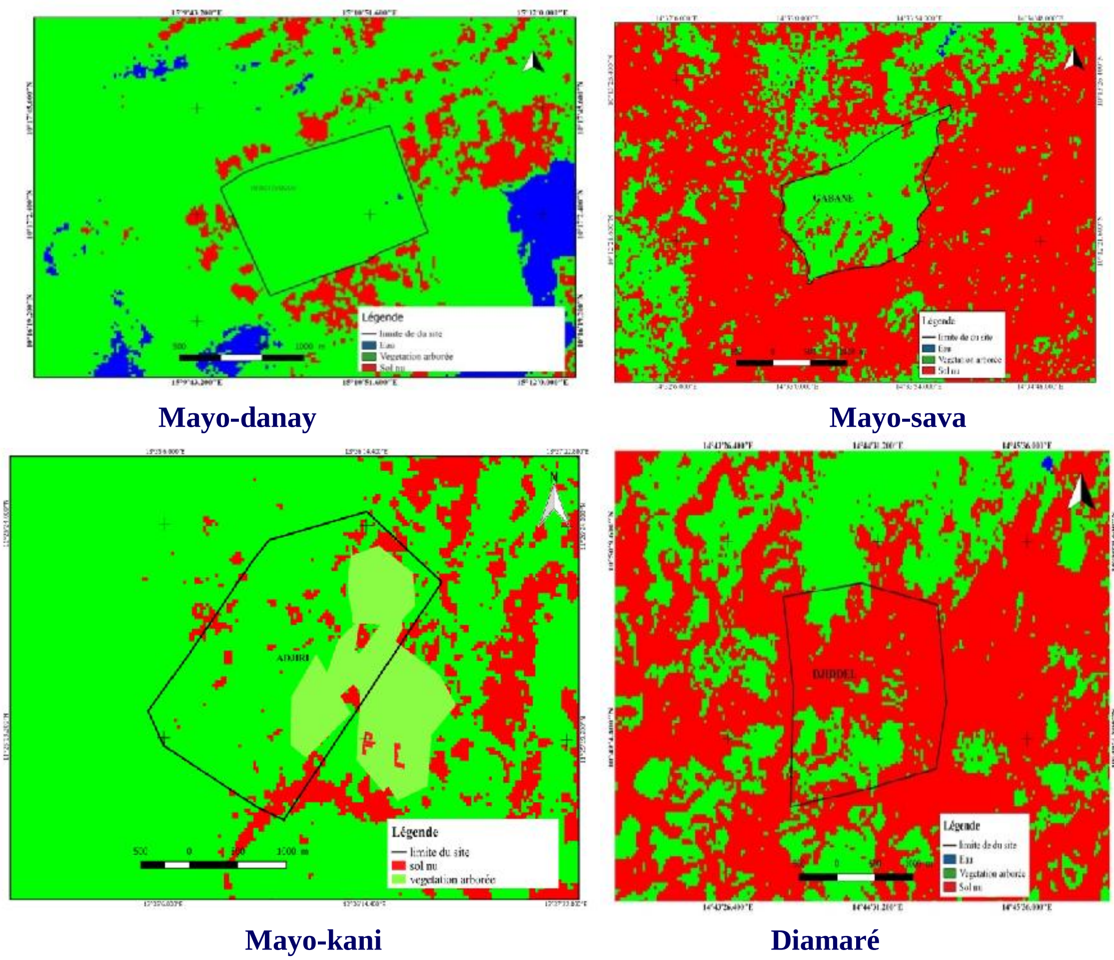

Figure 4: State of the plant cover between 2009 and 2018

Study of the compositional and structural diversity of ecosystems in restoration

Compositional diversity

The surveys carried out on the various vegetation formations allowed us to identify 72225 woody individuals divided into 82 species, 59 types and 26 families (Table 2). It appears from this table that the Mayo-kani grouping with 20023 individuals is the department that re-records the largest number of individuals therefore this department is the richest in biodiversity compared to other departments. The department of Mayo-sava is the one with the smallest number of individuals (15326). This difference in the number of individuals between the departments could be explained on the one hand by the fact that the maintenance, the protection and the management of the sites can be different and also by the fact that the environmental conditions can be also different.

Table 2: Compositional diversity

Components	Mayo-sava	Mayo-kani	Diamaré	Mayo-danay	Total
Trees	2780	2994	2491	2695	10960
Shrubs	12546	17029	14731	1 6959	61265
Species	82	87	82	84	168
Families	2325	26	24	26	59
Genres	68	63	62	60	133
Individuals	15326	20023	17222	19654	72225

Structure of the vegetation according to the height of the trees

The size of the species has been divided into five classes presented in Figure 5. This figure shows that individuals with heights between 1 and 5 m are more abundant. This reflects a strong regeneration of woody plants. While the individuals whose size is greater than or equal to 10 m are less in the sites which explains the scarcity of trees in the sites. This scarcity of trees in the sites in favor of the shrubs which are very abundant in the different sites is explained by the fact that sites have just been created. That is to say that the introduced species or even if they are protected have not yet had the time to have the important sizes and that species which were found were subjected to the anthropic pressure. These results are similar to those of Tchobsala (2011) which showed that the vegetation in the peri-urban savanna of Ngaoundéré is dominated by shrubs smaller than 5 m. This could be explained by the fact that anthropic pressure is more reduced on the shrubs in savannas because of the services which they make less important compared to the trees.

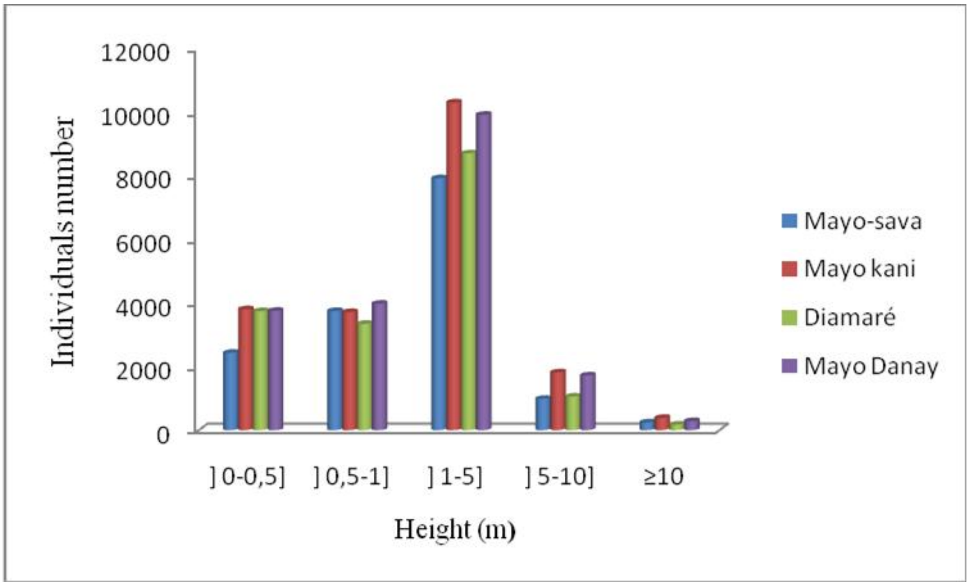

Figure 5: Distribution of species by height slice trees

Structure of the vegetation according to their diameter

Figure 6 shows the distribution of species in diameter class. It appears from this figure that the vegetation according to the size or height of the species has an "L" shape, which reflects the dominance of vegetation by individuals with a diameter of less than or equal to 5 cm. This class is very represented in the four sites is (66251 individuals), this large representative could be explained on one hand by the fact that the sites are minor and evolving and on the other hand it can be explained by the sites are threatened by manifold human activities. These results are similar to those of Tchobsala (2011) in the peri-urban savannas of Ngaoundéré which showed that the vegetation consists mainly of individuals with a diameter between 10 and 20 cm. This can be explained by the threats of man through his activities prevalent in the northern zone.

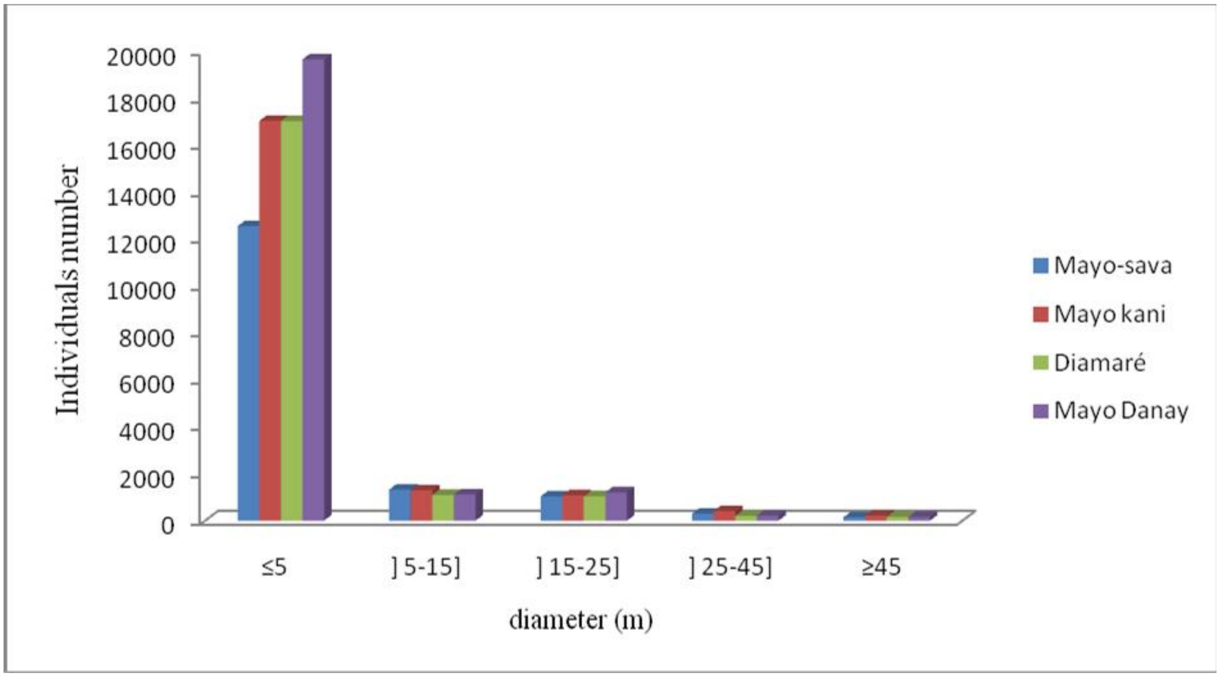

Figure 6: Distribution of species by diameter

Dispersion of species according to the dendrometric parameters

The dispersion of the species as according to dendrometric parameters was done by the Principal Component Analysis on the species / surveys file along three axes F1, F2, F1 and F2 with respectively 53.19%, 30.79%, 83, 98% percentages of eigen values (Figure 26). We observe a comparison between the number of individuals and the size which means that there is a very important positive correlation between the number of individuals or density and the size. This would be justified by the fact that the size of each individual encountered in the site was estimated, which is not the case for the parameter diameter at breast height. Species are grouped at the origin and form a cloud of points (Figure 7). This shows that the vegetation is constituted for most accidental species. We also observe a very shifted dispersion of *Anogeissus leiocarpus* and *Combretuma denogosum* that would be justified by their abundance and their high diversity in the sites.

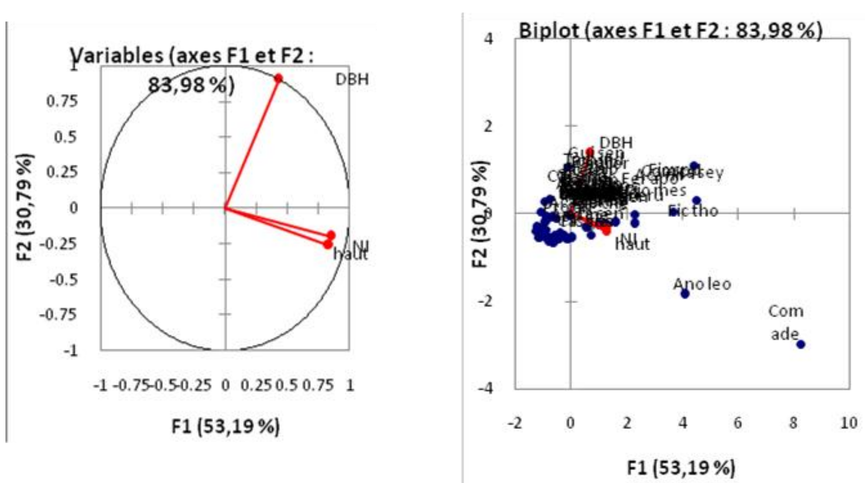

Figure 7: a-Distribution of dendrometric parameters b-Dispersion of ligneous plants

Conclusion and perspectives

At the end of this work, which aims to characterize ecosystems of the Green Sahel sites, the department of Mayo-kani and the Diamaré are dominated by the red color before installation of green sahel. They were strongly degraded. But after reforestation between 2009 and 2018, the department of Mayo-kani is dominated by green color. Reforestation can be regulate the effects of climate change. Concerning the composition and structure of flora of the four sites, 722978 individuals were counted divided into 87 species 59 genera and 26 families. 80% of the species are shrubs, which reflects a strong regeneration of species due to anthropic action through its multiple activities in the sites. The structure of vegetation show that the regeneration is important. So that we can talk about the reduction of climate change through these species, we need some technical and strategic conditions. It is wise to propose solutions that can reduce anthropogenic activities on vegetation, study the mechanisms of evolution and adaptation of each species in different areas and finally propose measures for sustainable management of these sites.

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