Impact of agricultural practices on vegetation structure and carbon sequestration in the North region Cameroon: the case of the Lagdo district

Abstract

In order to preserve the vegetation in the Lagdo subdivision of the Benue division in North region Cameroon with respect to agricultural practices and the effects of climate change, a study on the impact of agricultural practices was conducted in six plant formations and three riparian villages. This study therefore assessed the impact of agricultural practices on vegetation with a focus on the assessment of plant population structure and quantification of sequestered carbon stock. Floristic surveys in six vegetation formations (forest galleries, shrub savannahs, tree savannahs, 2015/2016 crop fields, fallows of two (02) years and more than two (02) years on 50 m x 50 m plots were conducted. Floristic richness analysis identified 50 species across the surveyed sites, which were divided into 40 genera and 23 families. The most represented families in the sites are Caesalpiniaceae, Euphorbiaceae, Combretaceae, Mimosaceae and Rubiaceae, which have 5, 4, 4, 4 and 3 genera respectively. The Shannon diversity index is highest in forest galleries (3.32), in wooded savannahs (3.04); medium in fallows of more than 2 years (2.33), 2-year fallows (2.21) and shrub savannahs (2.20) and lowest in crop fields. Regarding carbon sequestration, forest galleries have carbon stocks of 57.47 tC/ha, followed by shrub savannahs with stocks of 12.66 tC/ha and fallows of more than 2 years with 3.64 tC/ha. The crop fields (0.12 tC/ha) present the lowest values, however lower than those sequestered by shrub savannahs (1.03 tC/ha) and 2-year fallows (0.88 tC/ha). The results of the study on agricultural practices in the Lagdo subdivision therefore confirm the need for sustainable management of natural resources to combat climate change.

Keywords: Vegetation, impact, agricultural practices, carbon stock, North Cameroon

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1. INTRODUCTION

The world today is essentially dominated by farming (FAO, 2009). Agriculture occupies 63.7% of households and is the main activity in the world. Population growth has led to an increase in food demand that can only be met by intensifying agricultural activity (Ibrahima *et al.*, 2010). Sub-Saharan Africa must increase its agricultural production by 4% each year to meet this demand (Ibrahima *et al*., 2010). Thus, Africa loses 40,000 km^2 of its forest area each year, the largest losses are observed in the most forested countries according to FAO (2012), about 60% of deforestation is caused by agriculture (FAO, 2013). Agriculture in Cameroon is the main activity; the area of shrub savanna decreased by 10.8% from 1951 to 2006. The forest galleries have been attacked by farmers, their surfaces have decreased from 1844 ha to 784 ha, a decrease of over 50% from 1951 to 2001 (Tchotsoua, 2006). Moreover, this agricultural intensification also leads to the degradation (massive exploitation of their resources) of the savannahs of North Cameroon, which are rich in biodiversity. This degradation is observed through the anarchic cutting of wood, agriculture, overgrazing and pastoral fires (Tchotsoua *et al.*, 1996). These actions cause the loss of biodiversity of flora and fauna. Agriculture appears to be a very important element that negatively influences vegetation structure and carbon sequestration.

2. MATERIALS AND METHODS

2.1 Description of the study area and rationale for selecting the area

Our study area is located in three villages (Kate, Boucki, and Carrefour-Nari) in the Lagdo subdivision of the Benue division of the North region of Cameroon (Figure 2), which is one of ten (10) regions in Cameroon. The headquarter of region is Garoua. This study area extends between 8°20' and 9°05' North Latitude and between 13°15' and 13°50' East Longitude.

The interest in the choice of the site was focused on the pressure of anthropic activities, due to desertification of the area, the strong demographic pressure, the immigration of the population from the Far North in search of pasture in the North Cameroon region. The exposure of the population to poverty, the anarchic and illicit exploitation of non-timber forest products and timber products by the population to meet their needs and the expansion of agriculture reducing the area of forests.

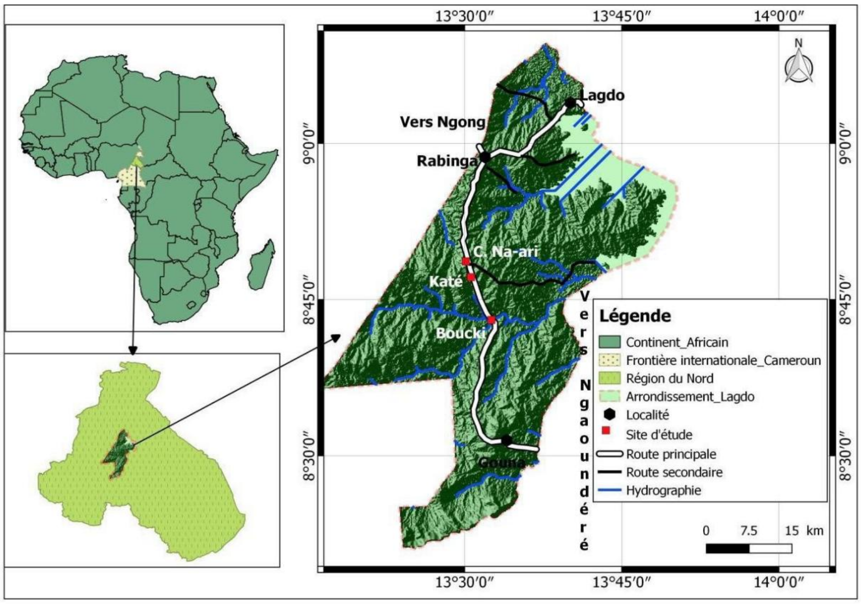

Figure 1 Map of the study area

2.2 Data Collection

The data collection consisted of an inventory of all woody species present in the area. Floristic surveys were carried out at 54 sites in the different villages in six different vegetation formations (forest gallery, fallows of 2 years and more than 2 years, fields, shrub savannahs and tree savannahs), i.e. nine surveys per vegetation formation. To study the impact of agricultural practices on vegetation, the location of the agricultural practice was chosen in each village according to the orientation of the local population. The experimental design is a two-factor *split-plot*. The first factor is the different villages (primary treatments), the second factor is the types of plant formations (secondary treatments) and the plots chosen in each type of plant formation constitute the replications.

Table 1: Experimental setup

Villages	Gf			His			Sar			J2years			j2years+.			Cha2015/2016		
Kate	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Boucki	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Carrefour-Nari	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Gf: Forest gallery; **Sa**: Shrub savanna; **Sar**: Tree savanna; **J2years**: Fallow for 2 years; **J2years+**: Fallow for more than 2 years and **Cha2015/2016**: Cultivated fields 2015/2016; **1**: Repetition in the different plant formations.

The inventory of plant species was carried out on a plot of 50 m x 50 m, 5 layons of 10 m width and 50 m length, according to the device of table 1 and figure 3. In each plot, all trees were surveyed and for all individuals with a height of 1.30 m, the following dendrometric parameters were measured: height, crown diameter, circumference at the base of the trunk at 1.30 cm from the ground. For trees whose main stem height is less than 1.30 cm, the number of shoots, the height and the diameter of the cluster were measured.

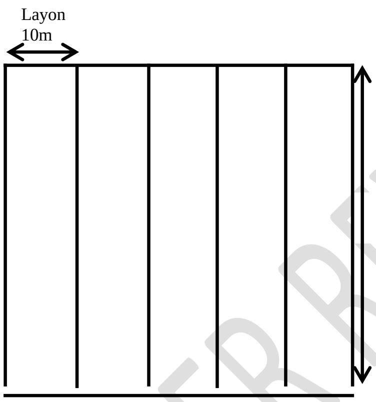

Figure 2: Reading device for woody inventory on a plot.

2.2.1 Data Analysis

The ecological characterization of vegetation is done through the following parameters: frequency, abundance, dominance and density. According to Braun-Blanquet (1932), relative frequency is the ratio expressed as a percentage between the number of records containing this species and the total number of records multiplied by 100. RF (%) = (A/B) x 100 with RF (%) = relative frequency, A= number of treatments containing the species and B= total number of treatments.

Abundance refers to the total number of individuals of the species. Species abundance can be absolute or relative. Absolute abundance is the total number of individuals of the species over the total number of individuals in the study site. Relative abundance is the ratio of absolute abundance to the total number of individuals in the community.

Dominance refers to the cover of individuals of each species and is expressed as a percentage.

Absolute dominance is the ratio of the total basal area of the species (STTe) to the total basal area of the sample (STTE). DA $=\frac{STTe}{STTE}$

Relative dominance or relative cover is the ratio of the species' total basal area (TBA) to the total basal area of the community (TBA) multiplied by 100 (Magurran, 1988).

$$\text{DR} = \frac{STTe}{STTC} * 100$$

The relative Curtis Importance Value is the sum of the relative density, relative frequency and relative overlap. IVCR (%) = FR+DR+DeR with IVCR: Curtis Importance Value; FR: Relative Frequency; DR: Relative Dominance; DeR: Relative Density

- **Shannon diversity index and Piélou equitability**

The calculation of the Shannon index is based on the hypothesis that diversity is a function of the probability Pi = Ni/N of the presence of each species i in a set of individuals. This index ranges from 0.5 bits (very low diversity index) to about 4.5 bits or exceptionally more in the case of large samples of complex communities (Frontier and Pichod-Viale 1993).

The Shannon diversity index calculated for each plant grouping is given by the following formula:

$H = -\Sigma pi \log_2 pi$

Pi = proportion of species i in the grouping.

Equitability (EQ) of Piélou (1966): EQ = ISH/log2N; it corresponds to the ratio between the observed diversity and the maximum possible diversity of the number of species N.

- **Jaccard's similarity coefficient**

It is given by the formula: **PJ $=\frac{c}{a+b-c}$x 100**

Where a = number of species in list a (Environment 1);

b = number of b-listed species (Environment 2)

c = number of species common to both environments.

It tends towards 0 when there is dominance and towards 1 when a maximum number of species participate in the cover (Frontier and Pichod-Viale 1993; Ndam 1998). The similarity between habitats is expressed by the high value of this index.

- **The Hamming distance**

The Hamming distance proposed by Daget and Poissonet (1971) quoted by Le Floch (1996) is added to this index to compare floristic surveys according to the formula :

H = 100 - PJ where PJ is the Jaccard index. The thresholds used are shown in Table 2.

Table 2: Threshold for comparison of floristic surveys by Hamming distance.

Threshold	Comparison
H< 20	Very small floristic difference
20<H<40	Low floristic difference
40<H<60	Average floristic difference
60<H<80	Strong floristic difference
80<H	Very strong floristic difference

2.2.2 Amount of carbon sequestered

- **Biomass Estimation**

The biomass of a tree represents the mass of its living plant tissue and is usually expressed in units of metric tons (t). It includes the above-ground part (leaves, branches and stems) and the underground part (roots).

- **Above-ground biomass estimate**

It was conducted in the 50 m x 50 m plots. The diameters at breast height (1.30 m from the ground). This phytomass was estimated by the indirect method, using a mathematical model, which considers the DBH. Among the equations found in the literature, the one used by Brown *et al.* (1997) was chosen for this study, because the coefficient of determination is highly significant (R^2 = 0.987). It was also developed for the Sahelian climate.

Ba = expo (-1.996+2.32*LN(DHP))

Where Ba is the aboveground biomass of the tree in kg and DBH is the diameter at breast height in m, expo is the exponential and LN is natural logarithm.

- **Root phytomass**

Root biomass was estimated using an equation used by Cairns *et al*. (1997), who showed that from aboveground phytomass, root phytomass (Br) can be obtained by the following equation:

Br (kg) = exp (-1.0587 + 0.8836 x LN (Ba)) Where Br = root phytomass, Ba = aboveground phytomass and LN = natural logarithm.

- **Estimation of the amount of carbon in the aerial phytomass**

The assessment of carbon in the different components is usually done by assessing the biomass present in the plots. Under the recommendations of the IPCC (2000), the majority of studies use an average value of carbon concentration of the vegetation 50% when more precise data are not available. It consists in assessing the amount of carbon from the biomass present in several (aerial) components.

QCv = B x Cv Where: QCv or $QC_{aérien}$ = vegetation carbon (tC/ha), B = Biomass (t/ha) and Cv = vegetation carbon concentration (0.5*).*

- **Estimation of the amount of carbon in the root phytomass**

To determine the amount of carbon in the root phytomass, we used the formula used by Saidou (2012).

QCr = Br x Cv

With : QCr = root carbon (tC/ha)

Br = Root biomass (t/ha)

Cv = vegetation carbon concentration (0.5).

3. RESULTS

3.1 Ecological characterization of species

3.1.1. Floristic richness

3.1.1.1 Within species

The analysis of floristic richness identified 50 species in all the sites studied. Table 3 lists the species inventoried, the most frequent species are: *Combretum collinum* (3517 individuals) and the relative frequency of 4.94%, as well as *Piliostigma thonningii* with 3567 inventoried individuals and a relative frequency of 4.94%, followed by *Combretum adenogonium* with a relative frequency of 4.7% with 1175. The species with a high value index of ecological importance are : *Piliostigma thonningii* (40.00%), *Combretum collinum* (34.00%), *Combretum* *adenogonium* (33.00%) and *Anogeissus leiocarpus* (32.00%).

Table 3: Species Richness, Frequency, Density, Dominance and Relative Ecological Importance Value Index.

Name of the species	DeR	EN	DR	IVC	Name of the species	DeR	EN	DR	IVC
Acacia seyal	0,05	0,47	0,6	1,1	*Ficus on*	0,12	1,18	0,06	1,4
Acacia ataxacantha	0,33	2,12	0	2,4	*Gardenia aqualla*	0,25	2,12	0,1	2,5
Acacia gerrardii	0,02	0,47	0,01	0,5	*Guiera senegalensis*	0,08	0,94	0,12	1,1
Acacia sieberiana	0,11	0,94	0,08	1,1	*Hexalobus monopetalus*	0,22	1,88	0,11	2,2
Acacia tortilis	0,69	3,29	0,89	4,9	*Lannea schimperi*	0,04	1,41	0,11	1,6
Afzelia africana	0,19	1,65	0,19	2	*Lophira lanceolata*	0,17	1,18	0,02	1,4
Allophylus africanus	0,01	0,47	3,25	3,7	*Parkia biglobosa*	0,01	0,47	0,04	0,5
Annona senegalensis	5,19	4,24	7,62	17	*Phyllanthus muellerianus*	0,75	1,41	0,42	2,6
Anogeissus leiocarpus	6,87	4	21	32	*Phyllantusreticulatus*	1,34	2,82	8,06	12
Antidesma venesum	0,03	0,71	0,03	0,8	*Piliostigma thonningii*	25,6	4,94	9,17	40
Balanites aegyptiaca	0,01	0,47	0	0,5	*Prosopis africana*	0,01	0,47	0,01	0,5
Bombax costatum	0,07	0,94	0,04	1,1	*Pterocarpus lucens*	0,2	1,65	0,02	1,9
Boswellia dalzielii	0,03	1,65	0,06	1,7	*Sarcocephalus latifolius*	0,19	1,18	0,05	1,4
Bridelia	0,2	3,7	0,4	4,5	*Senna siamea*	1,0	2,1	0,3	3,5

ferruginea	4	6	7			5	2	2	
Bridelia scleroneura	0,1	0,71	0,15	1	*Steganotaenia araliacea*	0,04	0,47	0	0,5
Cadaba glandulosa	0,24	0,94	0,11	1,3	*Sterculia setigera*	0,07	0,94	0	1
Combretum glutinosum	5,02	4,71	7,89	18	*Stereospermum kunthianum*	0,2	3,29	0,27	3,8
Combretum adenogonium	8,45	4,74	19,4	33	*Strychnos spinosa*	2,85	4	2,99	9,8
Combretum collinum	25,3	4,94	3,75	34	*Terminalia glauceusens*	6,18	3,76	8,13	18
Combretum nigricans	3,81	3,76	2,18	9,8	*Uapaca togoensis*	0,01	0,47	0,03	0,5
Dalbergia boehmii	0,83	2,82	0,23	3,9	*Vitellaria paradoxa*	0,12	2,35	0,14	2,6
Daniellia oliveri	0,04	0,47	0	0,5	*Vitex doniana*	0,01	0,71	0,09	0,8
Detarium microcarpum	0,09	1,65	0,27	2	*Ximenia americana*	0,22	1,88	0,06	2,2
Entada africana	0,98	1,88	0,93	3,8	*Ziziphus spina-christi*	0,29	2,35	0,06	2,7
Feretia apodanthera	0,42	2,12	0,1	2,6	*Ziziphus mauritiana*	0,83	2,35	0,42	3,6
					Total	100	100	100	300

RF: Relative frequency; **RD**: Relative density; **RD**: Relative dominance; **CRVI**: Relative Curtis value.

3.1.1.2 Gender diversity

The species inventoried in the Kate, Boucki and Carrefour-Nari locality are divided into 40 genera. Table 4 lists the genera, number of species, number of individuals, frequency and relative density. From this table, it appears that Acacia is the most diverse genus with five species which are *Acacia ataxacantha*, *Acacia gerrardii*, *Acacia seyal*, *Acacia sieberiana* and *Acacia tortili.* It is followed by *Combretum* genera which are : *Combretum adenogonium, Combretum collinum, Combretum glutinosum* and *Combretum nigricans.* The genera that have a high Curtis

Value Importance are: *Combretum* (93.6%), *Piliostigma* (39 .8%) and *Anogeissus* (31.8%).

Table 4: Richness, Frequency, Density, Dominance and Relative Curtis Value Importance and Number of genera.

Type	**NE**	**DeR**	**EN**	**DR**	**IVC**	**Type**	**NE**	**DeR**	**EN**	**DR**	**IVC**	
Acacia	5	1,2	7,3	1,6	10,1	*Hexalobus*	1	0,2	1,9	0,1	2,2	
Afzelia	1	0,2	1,6	0,2	2,03	*Lannea*	1	0	1,4	0,1	1,56	
Allophylus	1	0	0,5	3,3	3,73	*Lophira*	1	0,2	1,2	0	1,37	
Annona	1	5,2	4,2	7,6	17	*Parkia*	1	0	0,5	0	0,52	
Anogeissus	1	6,9	4	21	31,8	*Phyllantus*	2	2,1	4,2	8,5	14,8	
Antidesma	1	0	0,7	0	0,76	*Piliostigma*	1	26	4,9	9,2	39,8	
Balanites	1	0	0,5	0	0,48	*Prosopis*	1	0	0,5	0	0,49	
Bombax	1	0,1	0,9	0	1,06	*Pterocarpus*	1	0,2	1,6	0	1,87	
Boswellia	1	0	1,6	0,1	1,74	*Sarcocephalus*	1	0,2	1,2	0,1	1,42	
Bridelia	2	0,3	4,5	0,6	5,44	*Senna*	1	1	2,1	0,3	3,48	
Cadaba	1	0,2	0,9	0,1	1,29	*Steganotaenia*	1	0	0,5	0	0,51	
Combretum	4	43	18	33	93,6	*Sterculia*	1	0,1	0,9	0	1,01	
Dalbergia	1	0,8	2,8	0,2	3,89	*Stereospermum*	1	0,2	3,3	0,3	3,76	
Daniellia	1	0	0,5	0	0,52	*Strychnos*	1	2,8	4	3	9,84	
Detarium	1	0,1	1,6	0,3	2,01	*Terminalia*	1	6,2	3,8	8,1	18,1	
Entada	1	1	1,9	0,9	3,79	*Uapaca*	1	0	0,5	0	0,51	
Feretia	1	0,4	2,1	0,1	2,63	*Vitellaria*	1	0,1	2,4	0,1	2,6	
Ficus	1	0,1	1,2	0,1	1,36	*Vitex*	1	0	0,7	0,1	0,81	
Gardenia	1	0,3	2,1	0,1	2,47	*Ximenia*	1	0,2	1,9	0,1	2,16	
Guiera	1	0,1	0,9	0,1	1,14	*Ziziphus*	2	1,1	4,7	0,5	6,3	
							50	100	100	100	300	

NE: Number of species; **FR**: Relative frequency; **DeR**: Relative density; **DR**: Relative dominance; IVCR: Relative Curtis value importance.

3.1.1.3 Diversity within families

The species are divided into 23 families (Table 5). These families do not have the same importance or diversity, while some are represented by a single genus and species, others are represented by several genera and species. The Caesalpiniaceae, Euphorbiaceae, Combretaceae, Mimosaceae and Rubiaceae have 5, 4, 4, 4 and 3 genera respectively. The fact that a family has several genera does not necessarily imply that it is very diverse. The Rubiaceae, which includes 3 genera and 2 species, has only 119 individuals, i.e. a relative density of 0.85%/ha. At the same time, the Rhamnaceae with 2 genera and 2 species have 156 individuals, a relative density of 1.12% exceeding that of the Rubiaceae. The Balanitaceae and Sapindaceae are each represented by a single individual. The Combretaceae with 4 genera and 7 species are the most abundant in the locality. Their relative density is 55.70% and with their relative Curtis value 145%.

Table 5: Relative Richness, Frequency Density, Dominance, Importance Curtis Value of species and genera of families.

Family	NG	NE	DeR	EN	DR	IVC
Anacardiaceae	1	1	0,04	1,41	0,11	1,56
Annonaceae	2	2	5,4	6,12	7,72	19,2
Apiaceae	1	1	0,03	0,47	0	0,51
Balanitaceae	1	1	0,007	0,47	0	0,48
Bignoniaceae	1	1	0,2	3,29	0,27	3,76
Bombacaceae	1	1	0,07	0,94	0,04	1,06
Burseraceae	1	1	0,02	1,65	0,06	1,74
Caesalpiniaceae	5	5	27,03	10,8	9,96	47,8
Capparaceae	1	1	0,23	0,94	0,11	1,29
Combretaceae	4	7	55,7	26,6	62,4	145
Euphorbiaceae	4	6	2,46	9,88	9,15	21,5
Fabaceae	2	2	1,03	4,47	0,25	5,76
Loganiaceae	1	1	2,84	4	2,99	9,84
Mimosaceae	4	8	2,19	10,1	2,56	14,9
Moraceae	1	1	0,12	1,18	0,06	1,36
Ochnaceae	1	1	0,17	1,18	0,02	1,37
Olacaceae	1	1	0,21	1,88	0,06	2,16
Rhamnaceae	1	1	1,12	4,71	0,48	6,3
Rubiaceae	3	2	0,85	5,41	0,25	6,52
Sapindaceae	1	3	0,007	0,47	3,25	3,73
Sapotaceae	1	1	0,11	2,35	0,14	2,6
Sterculiaceae	1	1	0,07	0,94	0	1,01
Verbenaceae	1	1	0,01	0,71	0,09	0,81

	40	50	100	100	100	300

NG: Number of genera; **NE**: Number of species; **FR**: Relative frequency; **DeR**: Relative density; **DR**: Relative dominance; IVCR: Relative Curtis value importance.

3.1.1.4 Vertical structure of the plant population

Figure 4 shows the distribution of the plant population by height class in each plant formation. From this figure it is clear that individuals with heights between the interval [0-0.25[and [0.25-05] are more abundant in each plant formation. On the other hand, in the interval class [10, +∞[, we observe that the individuals in this interval is little represented in all the different plant formations; in this interval the forest galleries are more represented contrary to the cultivated fields and the shrubby savanna.

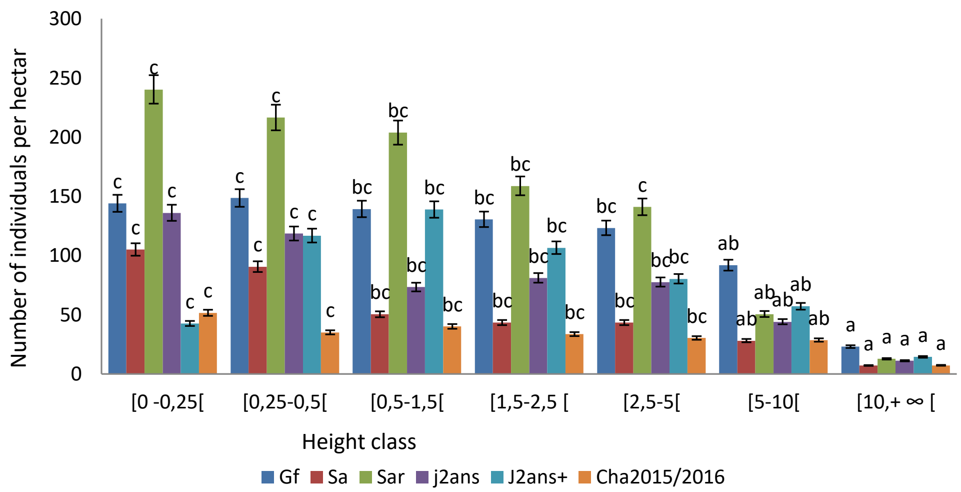

Figure 4: Plant population structure in height classes

Stems of the same letters are not significantly different at the 5% threshold**.**

Gf: Forest gallery; **Sa**: Shrub savanna; **Sar**: Tree savanna; **J2y**: Fallow 2 years; **J2y+**: Fallow more than 2 years; **Cha 2015/2016**: Crop fields 2015/2016.

3.1.1.5 Horizontal crown structure of the plant population

The horizontal structure shows a normal "L" shape, with many future stems in the interval [0 -0.25] and very few old subjects in the interval [5,+∞[(Figure 5). In the interval [0 - 0.25[, the locality of Boucki had more young individuals followed by Kate and Carrefour-Nari, but in the interval [5,+∞[, the Carrefour-Nari locality has a higher number of individuals followed by Katé and Boucki.

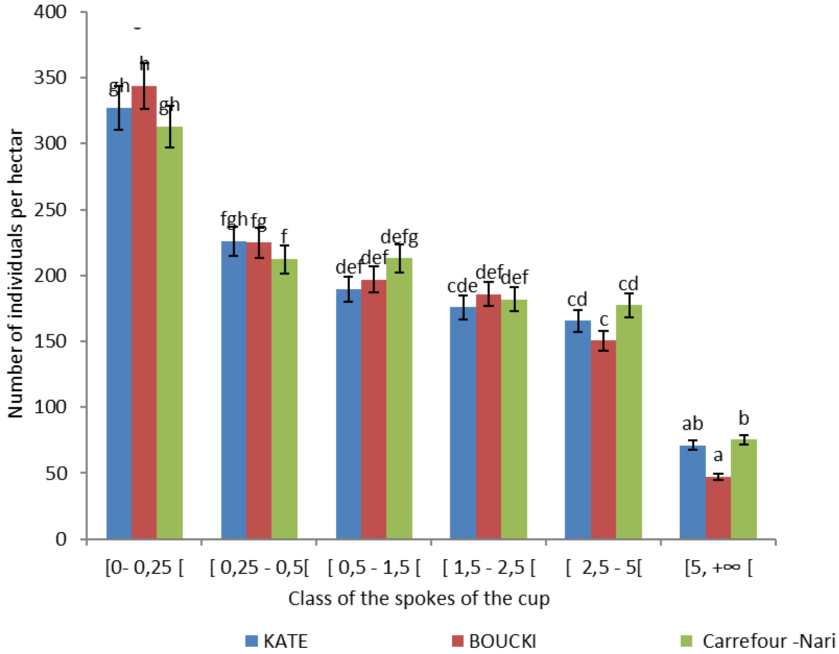

Figure 5: Plant population structure in crown class

Stems of the same letters are not significantly different at the 5% threshold**.**

3.1.2 Specific floristic diversity index

3.1.2.1 Shannon diversity index and Pielou equitality

Shannon's diversity index is higher in forest galleries (3.32), in tree savannas (3.04); medium in fallows of more than 2years (2.33), fallows of 2 years (2.21) and shrub savannas (2.20) and lower in 2015/2016 crop fields (1.69) as shown in Table 6. The same is true for Pielou's equitability which is higher in forest galleries (0.35) and also in tree savannas (0.34), while it is average in fallows of more than 2 years (0.233), 2-year fallows (0.235) and shrub savannas (0.21) and lower in 2015/2016 crop fields of Kate village (0.156). This means that plant biodiversity is very less dense in the 2015/2016 crop fields and less dense in the fallows and shrub savannas.

Table 6: Shannon Index (SIH), its inverse (D) and Piélou Equitability (PE).

	ISH	EQ	D
GF	3.32 ± 0.77 [b]	0,35 ± 0,09[b]	0,20 ± 0,13[a]
His	2,20 ± 0,17[a]	0,21 ± 0,02[a]	0,32 ± 0,02[ab]
Sar	3,04 ± 0,08[b]	0,34 ± 0,009[b]	0,16 ± 0,001[a]
J2years	2,21 ± 0,38[a]	0,23 ± 0,04[a]	0,33 ± 0,12[ab]
J2years+.	2,33 ± 0,19[a]	0,233 ± 0,02[a]	0,29 ± 0,06[a]
Cha2015/2016	1,69 ± 0,34[a]	0,20 ± 0,04[a]	0,47 ± 0,12[b]

Numbers with the same letters do not differ significantly at the 5% level**.**

Gf: Forest gallery; **Sa**: Shrub savanna; **Sar**: Tree savanna; **J2y**: Fallow 2 years; **J2y+**: Fallow more than 2 years; **Cha 2015/2016**: Cropping fields 2015/2016.

3.1.2.2 Jaccard's floristic similarity coefficients and Hamming distances

By applying Jaccard's test for floristic similarity in the different plant formations and in each village, the values in Table 7 were obtained. The coefficient of similarity in Kate village is average between fallows of more than 2 years and tree savannas (55.00%), between forest galleries and shrub savannas (46.00%). However, it is low between forest galleries and fields (26.31%), between shrubby savannahs and 2-year old fallows (25.00%), and between fields and fallows of more than 2 years (25.00%). The coefficient of similarity is very low between fields and shrubby savannahs (15.00%). In Boucki village, the coefficient of similarity is high between forest galleries and shrub savannahs (60.00%), medium between shrub savannahs and 2-year old fallows (54.54%), and between fallows of more than 2 years and shrub savannahs (48.00%). On the other hand, it is low in 2-year-old fallows and forest galleries (27.00%), between fields and fallows of more than 2 years (27.27%). Finally, in Carrefour-Nari village, the similarity coefficient is average between 2-year fallows and fallows of more than 2 years (57.14%), between shrub savannahs and 2-year fallows (56.25%), and between shrub savannahs and tree savannahs (55.00%). It is low between fields and forest galleries (30.00%).

Table 7: Jaccard's floristic similarity coefficients and Hamming distances between different environments

		Gf		His		Sar		J2years		J2years+.		Agr2015/2016	
		JP	H	JP	H	JP	H	JP	H	JP	H	JP	H
Kate	Gf	100	0	46	54	33,34	66,67	28,57	71,42	27,6	72,4	26,31	73,68
	His	46	54	100	0	31,81	68,18	25	75	30	70	15	85
	Sar	33,34	66,67	31,81	68,2	100	0	42,85	57,14	55	45	27,72	72,72
	J2years	28,57	71,42	25	75	42,85	57,14	100	0	42,1	57,9	26,31	73,68
	J2years+.	27,6	72,4	30	70	55	45	42,1	57,9	100	0	25	75
	Agr2015/2016	26,31	73,68	15	85	27,72	72,72	26,31	73,68	25	75	100	0
Boucki	Gf	100	0	42,85	57,1	60	40	27,28	72,73	38,23	61,76	32,25	67,74
	His	42,85	57,14	100	0	46,15	53,84	54,54	45,45	48	52	47,61	52,38
	Sar	60	40	46,15	53,8	100	0	33	67	35	65	38	62
	J2years	27,28	72,73	54,54	45,5	33	67	100	0	34,78	65,21	31,57	68,42
	J2years+.	38,23	61,76	48	52	35	65	34,78	65,21	100	0	27,27	72,72
	Agr2015/2016	32,25	67,74	47,61	52,4	38	62	31,57	68,42	27,27	72,72	100	0
Carrefour-Nari	Gf	100	0	40	60	44,73	55,26	38,7	61,29	35,13	64,86	30,3	69,69
	His	40	60	100	0	55	45	56,25	43,75	39,13	60,86	47,05	52,94
	Sar	44,73	55,26	55	45	100	0	39	61	44	56	39	61
	J2years	38,7	61,29	56,25	43,8	39	61	100	0	57,14	42,85	30	70
	J2years+.	35,13	64,86	39,13	60,9	44	56	57,14	42,85	100	0	32	68
	Agr2015/2016	30,3	69,69	47,05	52,9	39	61	30	70	32	68	100	0

Gf: Forest gallery; **Sa**: Shrub savanna; **Sar**: Shrub Savanna; **J2y**: Fallow 2 years; **J2y+**: Fallow more than 2 years; **Agra 2015/2016**: Agricultural fields 2015/2016.

3.2 Impacts of agricultural practices on carbon sequestration

3.2.1 On biomass production

Biomass production in the different plant formations is presented in Table 8. Forest galleries (114.95 t/ha) had the highest phytomass compared to tree savannahs (25.32 t/ha), fallows of more than 2 years (7.30t/ha), shrub savannahs (2.08 t/ha), fallows of 2 years (1.77t/ha) and crop fields 2015/2016 (0.25t/ha). These results are related to DBH, number and size of trees, which is why forest galleries have a higher biomass per hectare than savannahs, fallows and fields. The conversion of the forest space into cultivated fields by the phenomenon of wood cutting leads to a drastic decrease in phytomass.

Table 8: Biomass produced by woody plants according to the different plant formations (t/ha).

Plant formations	Aerial biomass	Root biomass	Total biomass
Gf	95,52 ± 28,17[b]	19,43 ± 5,09[c]	114, 95±33,26[bc]
His	1,57 ± 0,46[a]	0,51 ± 0,13[a]	2,08 ± 0,59[a]
Sar	20,38 ± 7,92[a]	4,94 ± 1,73[b]	25,32 ± 9,65[ab]
J2years	1,33 ± 0,54[a]	0,44 ± 0,15[a]	1,77 ± 0,69[a]
J2years+.	5,69 ± 0,91 [a]	1,61 ± 0,22[ab]	7,30 ± 1,13[ab]
Cha2015/2016	0,18 ± 0,03[a]	0,07 ± 0,01[a]	0,25 ± 0,04[a]

Numbers with the same letters do not differ significantly at the 5% level.

Gf: Forest gallery; **Sa**: Shrub savanna; **Sar**: Tree savanna; **D2y**: 2-year fallow; **D2y+**: Fallow more than 2 years; **Agra 2015/2016**: Crop fields 2015/2016.

3.2.2 Amount of Carbon Sequestered

The carbon stock is proportional to the quantity of biomass produced. Indeed, the largest carbon stocks per hectare are located in forest galleries with carbon stocks (57.47 tC/ha), followed by shrubby savannahs with stocks of 12.66 tC/ha and fallows of more than 2 years (3.64 tC/ha) (Table 9). Croplands (0.12 tC/ha) have the lowest values, but lower than those sequestered by shrub savannahs (1.03 tC/ha) and 2-year fallows (0.88 tC/ha).

Table 9: Amount of carbon sequestered by different plant formations (tc/ha)

Plant formation	QCA	QCR	Total
Gf	47,76 ± 14,08[b]	9,71 ± 2,54[c]	57,47 ± 16,62[bc]
His	0,78 ± 0,23[a]	0,25 ± 0,06[a]	1,03 ± 0,29[a]
Sar	10,19 ± 3,96[a]	2,47± 0,86[b]	12,66 ± 4,82[ab]
J2years	0,66 ±0,27[a]	0,22±0,07[a]	0,88 ± 0,34[a]
J2years+.	2,84 ± 0,45[a]	0,80 ±0,11[ab]	3,64 ± 0,56[ab]
Cha2015/2016	0,09 ±0,01[a]	0,03 ±0,007[a]	0,12 ± 0,01[a]

Numbers with the same letters do not differ significantly at the 5% level.

Gf: Forest gallery; **Sa**: Shrub savanna; **Sar**: Tree savannah; **J2y**: Fallow for 2 years; **J2y+**: Fallow for more than 2 years; **Cha2015/2016**: Cultivated fields 2015/2016.
ACQ: Amount of aerial carbon; **RCQ:** Amount of root carbon;

4. DISCUSSIONS

4.1 Floristic richness

In the present study the most dominant species families were the Ceasalpiniaceae and Combretaceae. In the Sudano-Sahelian woody stands of Senegal, Charahabil *et al*, (2013) found a strong expansion of Combretaceae which are justified by the rapid growth of their young plants and their great disseminative capacity. These results are different from those of Tchobsala (2011) in the peri-urban savannas of Ngaoundéré, who showed that it was the Hymenocardiaceae family that had a high Curtis Value importance (58.06¨%).

4.2 Vegetation structure

The structure of the population shows that woody plants with diameters greater than 150 cm have a low number of individuals, this is due to the solitude of old plants for the construction of houses for firewood and for the construction of sheds on the one hand and on the other hand to the environmental conditions of the fact that the adult plants are often destroyed by the violent wind or by the tornado. These results are similar to those of Mapongmetsem *et al.* (2016) in the peri-urban area of Bafia, who showed that the vegetation consists mainly of individuals with a diameter of less than 10 cm. Woody plants larger than 10m are less represented in the different vegetation formats. These results are similar to those of Tchobsala (2011) who showed that the vegetation in the peri-urban savannahs of Ngaoundéré is dominated by shrubs smaller than 5 m in height. Such a structure generally reflects good regeneration of the tree strata of plant communities (Cribellier, 2005). In fact, agriculture has a negative influence on the structure, biological diversity and distribution of species in natural savannahs, because the majority of large trees are cut down. Statistical analysis of variance shows a highly significant difference (0.001<0.05).

4.3 Floristic diversity index

The low Shannon's diversity index and Piélou's Equitability index obtained in the 2015/2016 crop fields, fallows and shrub savannahs would be due to anthropic pressures on these plant formations (Table 10). This result is different from Tchobsala (2011), who found almost equal values in these different plant formations. The diversity index (Shannon) is high in gallery forests and tree savannas with a value relatively close to that found by Sandjong *et al*. (2013) in Mozogo-Gokoro National Park and that obtained by Evaliste and Zapfak, (2014) in Waza National Park. This shows that disturbances, although visible in this plant formation, have had a strong influence on woody diversity, and that we are in the presence of relatively old, mature and structured stands. In the 2015/2016 crop fields, fallows and shrub savannahs, on the other hand, these diversity indices are low; this shows the strong disturbance of the environment, resulting in the disappearance of plant species. The high coefficient of similarity reflects a relativity of divergence between these environments, while the low coefficient of similarity between the different plant formations reflects the large number of similar species that they contain. These results agree with those of Ntoupka (1998) in the Sudano-Sahelian zone, who showed that the Hamming distances between the different plant formations are variable.

4.4 Carbon Sequestration

Similar results were obtained by the IPCC (2007) on carbon sequestration in large forest ecosystems in France and found that fallow lands sequester more carbon than fallow lands and natural formations. The low production of sequestered carbon in fields shows that the intensive practice of wood cutting on vegetation strongly reduces carbon sequestration in nature. Similar results were obtained by Zapfack (2005) in the forest region of Yaoundé where cultivated fields showed low carbon production (1.91 tC/ha/year).

Conclusion

The vegetation of the North is subject to intense agricultural activity. We are witnessing an accelerated degradation of the vegetation cover which is dynamic due to anthropic activities and threatened by climate change. The evaluation of the vegetation structure in each locality and in each plant formation allowed us to inventory 13907 individuals divided into 50 species, 40 genera and 23 families. Combretaceae with 7 genera and 4 species are the most abundant in the localities, their relative density is 55.70% and their relative Curtis Value importance is 145.00%. The Shannon index is higher in forest galleries (3.32), followed by savannah trees (3.04) and very low in crop fields (1.69). This low Shannon index in crop fields shows that agricultural practices have a strong influence on vegetation. Regarding carbon sequestration per hectare, the most important are located in forest galleries with carbon stocks (57.47 tC/ha), followed by wooded savannahs with stocks of 12.66 tC/h, contrary to crop fields (0.12 tC/ha), which present the lowest values. The results of the study on agricultural practices in the Lagdo district therefore confirm the need for sustainable management of natural resources to combat climate change.

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