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Quantification of carbon stocks and credit in the Sudano-Sahelian zone of Cameroon

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***Abstract*—This study was investigated to quantify the phytomass production, stock and credit carbon, as well as CO_2 emission in four Divisions (Mayo-Danay, Mayo-Kani, Mayo-Sava, Logone-Chari) and within four vegetation types (shrub savannah, wooded savannahs, protected areas, sacred forests) in the Sudano-Sahelian zone of Cameroon. In the experimental design that was a split-plot (4x4) x3, the Divisions were the main treatments, while the vegetation types were the sub-treatments. Results showed that herbaceou phytomass was higher in the Mayo-Danay protected areas (0.697375 t/ha/year), and was very low in the Logone-Chari shrub savannahs (0.00033 t/ha/year). The total amount sequestered carbon was higherin the Mayo-Kani sacred forests (80.239 tC / ha), and lower in the shrub savannah of Logone-Chari (18.918 tC / ha). The greatest monetary value was obtained in the sacred forests of Mayo-Kani ($2942.112 / ha). The largest amount of emitted CO_2 was observed in the Mayo-Kani sacred forests (294.211 tCO_2 / ha), the lowest accounting for the Logone-Chari shrub savannahs (69.367 tCO_2 / ha). The carbon credit generated by a good management of different vegetation types could improve the living standard of populations inhabiting the Sahelian zone of Cameroon. It is suggested that Cameroonian Government undertakes biodiversity conservative measures to sustainably protect the environment by setting up a REDD+ mechanism in this part of the country where deforestation is very pronounced.**

Keywords—Vegetation types, carbon sequestration, carbon credit, phytomass, Sudano-Sahelian zone.

I. INTRODUCTION

Climate change is one of the biggest threats faced by the inhabitants of Sahelian zones. The demographic explosion observed ie 2.4% per year against a global average of 1.24% [28] in recent decades has generated several concerns in terms of food, health and insecurity in sub-Saharan Africa [14]. To satisfy this demand, inhabitants exert pressure on the savannahs, which is fragilized by ecosystem degradation, global warming of the earth, climatic variation, reduced fallowing time, hunger, soil infertility, drying up of wells, persistence of diseases such as malaria, cholera, avian influenza, bovine influenza, swine flu, Ebola [36]. To this is added their daily activities that emit greenhouse gases (GHGs), contributing to global warming. When greenhouse gas emissions increase, the climate is affected, the overall weather situation changes, and the average temperatures rise [13]. As part of UN-REDD climate change policies, allometric equations used in quantification of biomass, carbon credit and carbon dioxide (CO_2) have become a research concern [18] that deserves to be studied. Hence, the preservation and reconstruction of the Sahelian ecosystemic heritage is fundamental from the environmental, ecological and economic points of view. Carbon sequestration and its cost value represent an important potential in the Sahelian environment where they can boost local populations by offering them opportunities for improving their living conditions [6]. In order to control climate change and combat desertification, African farmers have developed several adaptation options to cope with current climate variability [3]. Other research topics have focused on state and prospects of the Forest Reserve [34]; anthropogenic actions related to climate change [23]; information system for the integrated analysis of land use changes in the far north of Cameroon [15], as well as the impacts of anthropogenic disturbances (pasture, fire and logging) on dynamics of the savannah in the Sudano-Sahelian zone [27]. To the best of our knowledge, no work has yet been conducted on the quantification of stock and carbon credit in the Sudano-Sahelian zone of Cameroon. This study aims at measuring the impact of deforestation on carbon stock and credit in the Sudano-Sahelian zone in Far-North Cameroon. Specifically, it involves assessing the amount of sequestered carbon, estimating its monetary value and determining the amount of carbon sequestered in equivalent CO_2. How to assess the amount of carbon stored by plant formations in the current state? The assumption is that allometric equations associated with field surveys can be used to quantify the carbon stock.

II. MATERIAL AND METHODS

A. Presentation of the study area

Investigations took place in four Divisions, namely Mayo-Danay, Mayo-Kani, Mayo-Sava and Logone-Chari (fig. 1). They were carried out on four vegetation types (Shrubs savannahs, wooded savannahs, sacred forests and protected areas). This study area was chosen because of its exposure to the advanced of desert and was also considered as the gateway to the desert in Cameroon. These Divisions belong to the Far-North region of Cameroon. The climate is of the Sudano-Sahelian type, characterized by alternated long dry season from October to June and short rainy season between July and September. The maximum rainfallis recorded between August and September. The area is occupied by a large plain stretching from Mandara Mountains to the borders of Lake Chad [23]. It covers 34263 km² and extends between latitudes 10 and 13 degrees North and Longitudes 13 and 15 degrees East [15]; [26]. It is launched in the east by two permanent streams (the Logone and Chari), in the West, and the North by the Federal Republic of Nigeria, in the South by the North region of Cameroon.

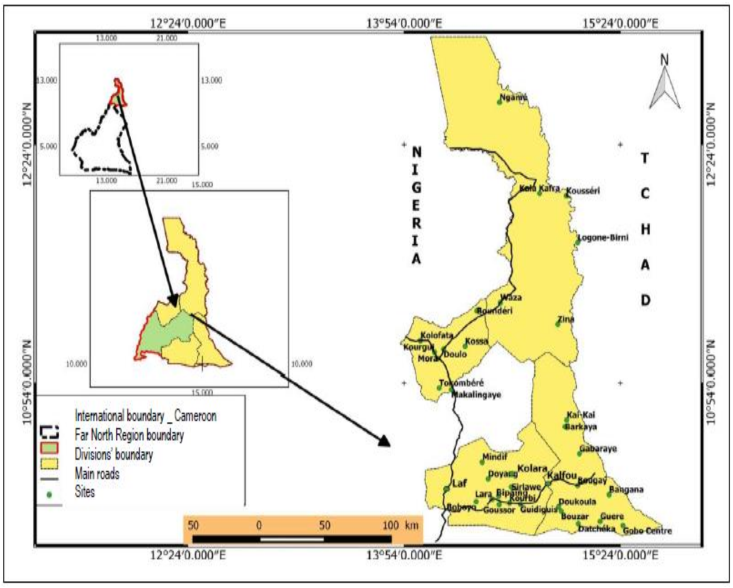

Figure 1: Localization of the study area

B. Measurement of dendrometric parameters

The experimental setup is a 2-factor split-plot (4 x 4) x 3. The Departments (Mayo-Danay, Mayo-Kani, Mayo-Sava and Logone-Chari) are considered as the main treatments, while the vegetation types (shrub savannahs, tree savannahs, protected areas and sacred forests) chosen in each of the four Division are the secondary treatments, and the 100 mx 100 m plots in each vegetation types consideredeed sa repetitions as described by [35]; [32]. A total of 48 hectares were studied, 12 hectares per Department. Each site was surveyed and then sampled using the floristic surveys method carried out on 10 layons of 10 m wide and 100 m long. Measurements of the dendrometric parameters were carried out on trees heights measured with a graduated slat, the tuft diameters also determined with agraduated slat, while the number of individuals was counted for a given DBH (diameter at breast height 1.30 m) was determined on the basis of one meter ribbon [10]. The identification of the species was carried out systematically on the spot or in the laboratory (Garoua fauna school meadow and the Wakwa IRAD herbarium).

C. Estimation of herbaceous stratum phyomass

The production of herbaceous phytomass was measured at the beginning of plot placement. To evaluate this phytomass, five (5) circles of one (01) meter radius were measured using a tape measure. The measurements were systematically carried out at the intersection of two diagonals of each 100 m × 100 m plot. In total, 5 circles per hectare were retained as a total of 240 circles [7]. Fresh herbs (samples) and discards were harvested and weighed on site. Just a small amount (wrist) was recovered and weighed again and it was this quantity, which was brought back into dried ovens at the University of Ngaoundere and then weighed until achieving a constant result.

D. Estimation of the above ground trees phytomass

Phytomass is estimated by the indirect method, using a mathematical model, taking into account diameter at breast height and height of trees. Among the equations found in the literature, that used by [2] and [1] was chosen for this study because the coefficient of determination is highly significant ($R_2 = 0.987$). It has also been developed in the Sahelian climate.

Ba = exp (-3.114 + 0.9719 Ln (DBH^2))

Where: Ba is the aerial biomass of the tree in kg, DBH is the breast height diameter in m.

F. Estimation of root phytomass

Root biomass was accurately estimated using the equation used by [5], which states that starting from the aerial phytomass, the root phytomass (Br) can be obtained by the following equation:

Br (kg) = exp (-1.0587 + 0.8836 x ln (Bt))

Where: Br is the phytomass root; Bt is the total phytomass above the soil.

Thus, from the aerial phytomass, one can calculate the root phytomass which is also expressed in tons per hectare.

G. Estimation of the amount of carbon in the above ground phytomass

The amounts of carbon were calculated according to the formula given below by [21].

QCv = B x Cv

where: QCv or QCabove groundis thevegetation carbon (tC/ha); B is the vegetation biomass (t/ha); Cv is carbon concentration of the vegetation (0.5).

H. Estimation of the amount of carbon in the root phytomass

The final carbonvalues in the root phytomass was determined used the formula proposed by [21] and [30].

QCr = Br x Cv

where: QCr is the root carbon (tC/ha); Br is the Root biomass (t/ha); Cv is the vegetation carbon concentration (0.5).

I. Estimation of the total quantity of carbon formedin each type of plant

It was simply obtained by the summation of the quantities of carbon of all the components (above ground, root) using the formula:

TotalQC = Above groundQC+ RootQC+ HerbaceousQC

J. Evaluation of the ecological service

The ecological service was estimated using the 44/12 ratio, corresponding to the CO_2/C ratio that represents the molecular weight used to convert the carbon stocks into CO_2 sequestered by the forest. Then, this amount of CO_2 was subsequently evaluated in monetary value using the ecosystem service value estimated at USD 10/tCO_2 [12], assuming that1 US Dollar = 593.95 CFA, value of 30.08.2016).

K. Calculation of Carbon Dioxide (CO_2) equivalent or absorbed

The amount of carbon dioxide (CO_2) emitted into the atmosphere can be calculated using the formula used by [37] in Mali as follow:

CO_2 = StC * PMCO_2 / PMC

where: CO_2 is Carbon dioxide; AGB is the total aerial biomass of the sample site; PMCO_2 is the molecular weight of carbon dioxide (44) and PMC is the molecular weight of carbon (12).

L. Statistical analysis

The data collected in the field were classified in Excel and analyzed. The STATGRAPHICS Plus 5.0 software was used for the analysis of variance (ANOVA), while Duncan Multiple rang test was used to verify the difference between treatments.

III. RESULTS

A. Evolution of herbaceous phytomass in different Division

The production of phytomass from the grass stratum varies from one plant formation to another, from one department to another and from one year to another. The shrub savannahs show a similar amount of phytomass and lower during the two years compared to other plant formations. On the other hand, shrub savannahs present very low amounts of phytomass in the Logone-Chari (0.00033 t / ha in the first year). The production of the grassy phytomass according to department shows that in the shrubs savannah, it is identical in all the Departments in first year except that encountered in the Logone-Chari, whereas in the second year it is similar. The quantity of the phytomass estimated in the wooded savannah is very high in the first year that in the second, it varies significantly (0.02 <0.05). In the wooded savannah according to the Departments, there is a very highly significant difference (0.000<0.001) between the phytomass obtained in the Departments from the first year to the second year and the most important phytomass is encountered in the Mayo-Dany (0.4734 t / ha) in the first year, the lowest is obtained in the Logone-Chari (0.030975 t / ha) in the second year. In protected areas, the phytomass produced is almost identical over the two years. The phytomass obtained in the protected areas according to the Departments is almost similar during the two years. This phytomass is highest in Mayo-Danay (0.697375 t / ha) in the first year and very low in Mayo-Sava (0.09285 t / ha) in the second year. The production of phytomass from the grass stratum in the different types of vegetation formation shows that the protected areas in Mayo-Danay (0.697375 t / ha) in the first year have the largest phytomass compared to the other types of formation (Fig.2). There is a very highly significant difference (0.000 <0.001) between the phytomass of the first and second year in the sacred forests. In sacred forests, the amount of phytomass obtained by the Departments is very highly significant (0.0000 <0.001) between the two years. It is greater in Mayo-Danay (0.496625 t / ha) in the first year and less in the Logone-Chari (0.1112 t / ha) in the second year. To this end, on the whole, protected areas, wooded savannahs and sacred forests are dominated by *Loudetia* spp., *Hyparrhenia* spp. In these four types of vegetation formations. It is in the shrub savannah that the animal's apple and the herbaceous phytomass is clearly consumed. While in other types of training times access is prohibited to animals and the phytomass is significantly important.

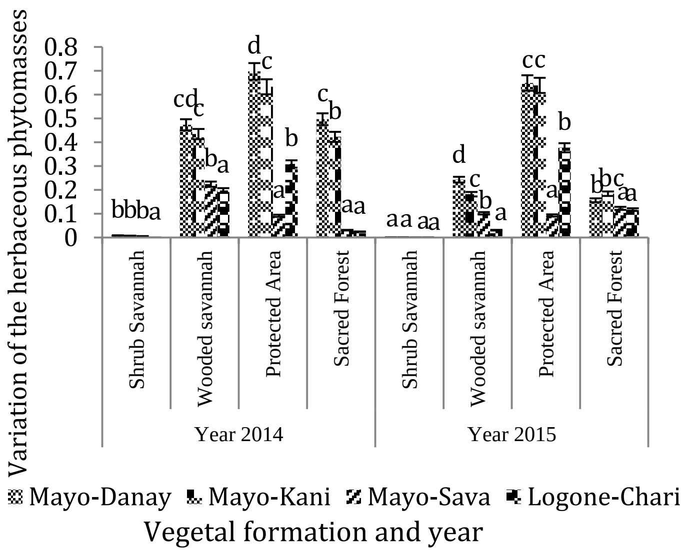

Figure 2. Quantification of herbaceous phytomasse according to different vegetation types between Departments

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B. Estimation of abovegroung phytomasses in different vegetation types of formation

The aerial phytomass varies significantly between years, Departments and plant formations (0.000 <0.001). The production of these aerial phytomass varies from one plant formation to another, from one department to another and from one year to a (0.001 <0.01). In the wooded savannahs according to the departments, there is a very highly significant difference (0.000<0.001) between the phytomass obtained in the Departments from the first year to the second year and the most important phytomass is encountered in the Mayo-Dany (231.84 t / ha) in the first year, the lowest in Mayo-Sava (129.21 t / ha) in the second year (Table 1). The production of aerial phytomass according to department shows that there is a highly significant difference (0.004<0.01) between the biomass of shrub savannah differences in all departments over the two years. Overall, the first year has a slightly higher amount of aerial phytomass compared to the second year. The sacred forests in the Mayo-Kani have a large amount of phytomass (133.62±1.72 t/ha) in the first year. It is more average in the Logone-Chari (78.78±1.73 t / ha) in the second year because in this department the sacred forests are being transformed in a sacred house. The phytomass obtained in the protected areas according to the Departments has a significant difference (0.04 <0.05) according during the two years. This biomass is much more prevalent in Mayo-Danay (131.73±2.87 t / ha) in the first year, it is much lower in Mayo-Kani (107.37±2.3 t / ha) in the second year. These values have taken into account the DBH and the height of the trees, which justifies the greatest amount of biomass in the sacred forests to that of the shrub savannah because in the latter only twigs or young feet are found in the shrub savannahs. Cause deforestation causing dizzy decline in biomass.

Table 1. Estimation of aerial phytomass in the different types of vegetation formation according to year (t / ha)

Year 2014						
	WS	SS	SF	PA	Av	
MD	$115.92\pm2.8_{a}^{C}$	$51.06\pm3.46_{a}^{D}$	$119.35\pm2.09_{b}^{B}$	$131.73\pm2.87_{a}^{A}$	104.51 ± 36.2	PV
MK	$104.72\pm2.3_{b}^{C}$	$47{,}79\pm4.04_{ab}^{D}$	$133.62\pm1.72_{a}^{A}$	$112.37\pm1.15_{b}^{B}$	99.62 ± 36.6	<0.001
MS	$74.37\pm2.3_{c}^{C}$	$33.71\pm1.72_{b}^{D}$	$121.51\pm2.86_{b}^{A}$	$107.88\pm2.86_{b}^{B}$	84.36 ± 39.1	<0.001
LC	$71.73\pm0.57_{c}^{C}$	$31.17\pm2.95_{b}^{D}$	$81.44\pm2.8_{c}^{B}$	$129.62\pm2.31_{a}^{A}$	78.49 ± 40.4	<0.001
Av	91.68 ± 22.02	40.93 ± 9.95	113.98 ± 22.58	120.4 ± 12.03		<0.001
PV	<0.01	<0.01	<0.001	<0.01		
Year 2015						
	WS	SS	SF	PA	Av	PV
MD	$113.15\pm1.73_{a}^{C}$	$49.77\pm2.3_{a}^{D}$	$120.12\pm2.88_{b}^{B}$	$131.12\pm4.04_{a}^{A}$	103.54 ± 36.6	<0.001
MK	$106.16\pm3.46_{b}^{B}$	$49.12\pm2.88_{a}^{C}$	$133.4\pm1.73_{a}^{A}$	$107.37\pm2.3_{c}^{B}$	99.01 ± 35.5	<0.001
MS	$74.6\pm2.3_{c}^{C}$	$30.6\pm1.15_{b}^{D}$	$121.29\pm2.88_{b}^{A}$	$109.12\pm1.73_{c}^{B}$	83.9 ± 40.6	<0.001
LC	$72.14\pm1.15_{c}^{C}$	$32.17\pm2.89_{b}^{D}$	$78.78\pm1.73_{c}^{B}$	$128.95\pm3.51_{b}^{A}$	78.01 ± 39.7	<0.001
Av	91.51 ± 21.16	40.41 ± 10.44	113.39 ± 23.84	119.14 ± 12.63		
PV	<0.001	<0.01	<0.001	<0.001		

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The numbers which have the same letters at the same ling are not significantly differently at the top indicated.
WS= Wooded Savannah, SS= Shrub Savannah, SF= Sacred Forest, PA= Protected Area, MD= Mayo-Danay, MK= Mayo-Kani, MS= Mayo-Sava and LC= Logone-Chari; Av=average

C. Quantification of Root Phytomass

The root phytomass varies very significantly between years, Departments and plant formations (0.000<0.001). The amount of rooted phytomass encountered in wooded savannahs is almost similar according to year, it varies significantly (0.001<0.01). The most important phytomass is found in the Mayo-Dany (23.13 t / ha) in the first year, the lowest in Logone and Chari (15.13 t / ha) in the second year. Shrub savannahs show the same amount of phytomass and weaker during two years compared to other types of vegetation. The lowest phytomass is observed in shrub savannahs (7.13 t / ha in the second year) in Mayo-Sava (fig.3). The production of the phytomass root according to department in the shrub savannahs is much less compared to the plant formations. There is a highly significant difference (0.005 <0.01) between the Departments. Concerning sacred forests, the amount of underground biomass varies slightly between years. In protected areas, the phytomaase produced is almost identical over the two years. Overall, the first year has a slightly higher amount of root crop compared to the second year. The phytomass obtained in the protected areas according to the Departments has a significant difference (0.02 <0.05) between the departments during the two years. This phytomass is highest in Mayo-Danay (25.89 t / ha) in the first year and very low in the Mayo-Sava (21.7 t / ha) in the second year. Sacred forests in the Mayo-Kani have a large amount of underground phytomass (26.22 t / ha) in the first year and lowest in the Logone-Chari (16.44 t / ha) in the second year due to the transformation of forests sacred houses. These values have taken into account the DBH and the height of the trees, which justifies the greatest amount of root biomass in the Sacred Forests to that of the shrub savannah because in the latter it is observed that twigs or young feet in shrub savannahs cause of the high level of deforestation causing the vertiginous decrease of underground biomasses.

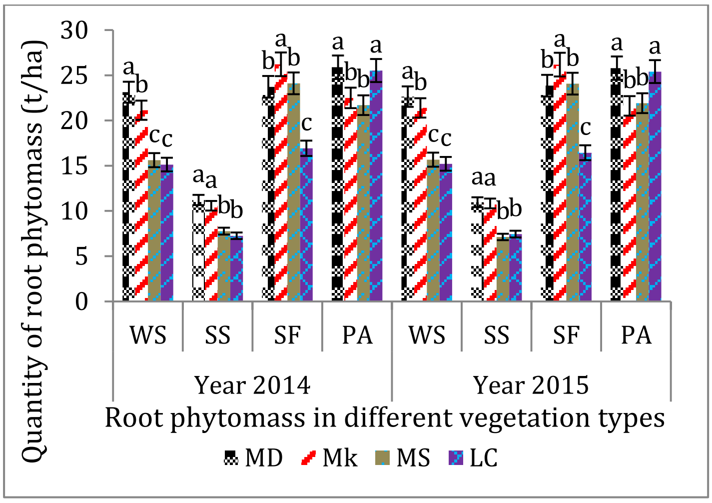

Figure 3. Varation of root phytomass in the different types of vegetation types according to the year (t/ha)

The figures having the same letters are not significantly different at the shord indicated.
WS= Wooded Savannah, SS= Shrub Savannah, SF= Sacred Forest, PA= Protected Area, MD= Mayo-Danay, MK= Mayo-Kani, MS= Mayo-Sava and LC= Logone-Chari

D. Amount of phytomass carbon in the herbaceous stratum

The amount of carbon in the phytomass of the grass stratum varies from one plant formation to another, from one department to another and from one year to another. Shrub savannahs have an almost similar and lower amount in first and second years compared to other types of vegetation formation. This quantity is estimated in wooded savannahs and is very high in the first year, whereas in the second it varies significantly (0.02 <0.05). On the other hand, shrub savannahs present very low amounts of carbon in the Phytomass in the Logone-Chari (0.0002 tC / ha) in the first year. The production of carbon in the grassy phytomass according to department shows that in the shrubs savannah it is identical in all the Departments in first year except that met in the Logone-Chari, whereas in the second year it is similar. In protected areas, the amount of carbon in phytomass is almost identical over the two years. There is a very highly significant difference (0.000 <0.001) between the quantity of the first and second year in the sacred forests. Carbon production in the herbaceous phytomass in the different types of vegetation formation shows that the protected areas in Mayo-Danay (0.3487 t / ha) in the first year have the highest carbon content compared to other types of vegetation (table 2). Formation because the medium is defended. The amount of carbon in the phytomass obtained in the protected areas according to the Departments is almost similar over the two years; this quantity is highest in Mayo-Danay (0.3487 tC / ha) in the first year and very low in Mayo-Sava (0.0457 tC / ha) in the first year. In the forest savannahs according to the departments, there is a very highly significant difference (0.000 <0.001) between the amount of carbon in this phytomass obtained in the Departments from the first year to the second year and the greatest quantity is encountered In Mayo-Dany (0.2367 tC / ha) in the first year, the lowest is obtained in the Logone-Chari (0.0155 tC / ha) in the second year. In sacred forests, the amount of carbon obtained in the phytomass by the Departments is very highly significant (0.0000 <0.001) between the two years. It is larger in Mayo-Danay (0.2483 tC / ha) in the first year and less in the Logone-Chari (0.0586 tC / ha) in the second year. This low amount of carbon in the grassy stratum in shrub savannahs may be justified because of soil degradation since it is in the shrub savannahs that the animals are sucking, the anthropogenic activity is very remarkable and the amount of carbon in the soil Phytomass is clearly destroyed. Whereas in protected areas and sacred forests access is prohibited to animals and the amount of carbon in the phytomass is potentially significant.

Table 2. Variation of phytomass carbon in the herbaceous stratumbetween vegetation types according to the year

	SS	WS	PA	SF	PV
Year 2014					
MD	0.0043_{d}^{C}	0.2367_{b}^{A}	0.3487_{b}^{B}	0.2483_{bc}^{A}	0.02
MK	0.0039_{c}^{C}	0.2172_{b}^{A}	0.3165_{b}^{B}	0.2114_{b}^{A}	0.01
MS	0.0029_{b}^{C}	0.1121_{a}^{A}	0.0457_{b}^{D}	0.0154_{ab}^{AB}	0.001
LC	0.0002_{a}^{A}	0.0987_{c}^{D}	0.1546_{a}^{C}	0.0123_{a}^{B}	0.003
PV	0.0000	0.002	0.001	0.03	0.000
Year 2015					
MD	0.0007_{b}^{A}	0.1216_{d}^{B}	0.3244_{c}^{D}	0.0782_{b}^{C}	0.000
MK	0.0006_{ab}^{A}	0.091_{bc}^{B}	0.3193_{c}^{C}	0.0921_{b}^{B}	0.003
MS	0.0004_{a}^{A}	0.0509_{b}^{B}	0.0464_{a}^{B}	0.0613_{a}^{B}	0.14
LC	0.0003_{a}^{A}	0.0155_{a}^{B}	0.1885_{b}^{D}	0.0586_{a}^{C}	0.000
PV	0.13	0.000	0.001	0.14	0.006

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The numbers which have the same letters at the same ling are not significantly differently at the top indicated.
WS= Wooded Savannah, SS= Shrub Savannah, SF= Sacred Forest, PA= Protected Area, MD= Mayo-Danay, MK= Mayo-Kani, MS= Mayo-Sava and LC= Logone-Chari, PV= P-value

E. Amount of phytomass carbon in the shoot

The amount of carbon in aerial phytomass varies significantly between years, Departments and plant formations (0.01<0.05). The amount of carbon in the aerial phytomass encountered in wooded savannahs is almost similar as a function of year. In the wooded savannahs according to the Departments, there is a highly significant difference (0.005 <0.01) between the Departments in terms of years. Carbon in aerial phytomass is highest in Mayo-Danay (57.96 tC / ha) in the first year, the lowest in Logone and Chari (35.865 tC / ha) in the first year. Shrub savannahs have an almost identical amount of carbon in near-identical aerial phytomass, lower in the first and second years than in other types of vegetation. The production of carbon in aerial phytomass according to department in shrub savannahs is very low compared to plant formations. There is a highly significant difference (0.002 <0.01) between Departments, years and types of vegetation formation. This quantity is much more common in Mayo-Danay (25.532 tC / ha) in the first year, the lowest in Mayo-Sava (15.30 tC / ha) in the second year (Fig. 4). In sacred forests, the amount of carbon in aerial phytomass according to the Departments is very highly significant (0.000 <0.001) between departments and types of vegetation formation and year. It is larger in the Mayo-Kani (66.8125 tC / ha) in the first year and smaller in the Logone-Chari (39.39 tC / ha) in the second year due to the transformation of sacred forests in sacred houses. In protected areas, the carbon in aerial phytomasse produced is almost similar in both years. Overall, the first year shows a slightly higher amount of carbon in the aerial phytomass compared to the second year, whereas the statistical analysis shows that there is a very highly significant difference (0.000 <0.001). Carbon in the aerial phytomass obtained in the protected areas according to the Departments has a highly significant difference (0.001 <0.01) between the départements during the two years. This amount is higher in Mayo-Danay (65.86 tC / ha) in the first year and very low in the Mayo-Kani (53.685 tC / ha) in the dry and second year. The fluctuation of the amounts of carbon in the different types of plant formation is due to the fact that some are protected and others are left to the pressure of the teeth of the axes.

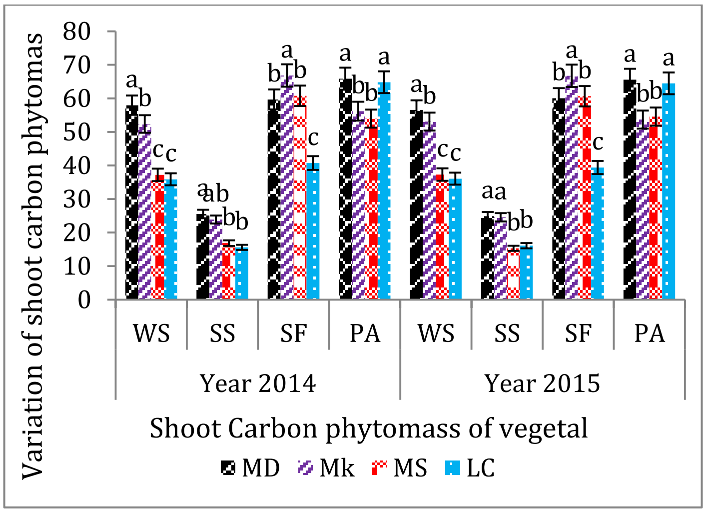

Figure 4. Variation of shoot carbon phytomass between vegetation types according to the year (tC/ha)

The figures having the same letters are not significantly different at the shord indicated.

MD= Mayo-Danay, MK=Mayo-Kani, MS=Mayo-Sava, LC= Logone-Chari, WS= Wooded Savannah, SS= Shrub Savannah, SF= Sacred Forest, PA= Protected Area.

F. Amount of root phytomass carbon in vegetation types

The amount of carbon in the root crop varies significantly between years, Departments and plants formations (0.01<0.05). The amount of carbon in the underground phytomass found in wooded savannahs is almost similar as a function of year. Shrub savannahs show a much smaller amount of carbon in the near-identical root crop over two years compared to other crop types. In sacred forests, the amount of carbon obtained in the underground biomass varies slightly between years (0.01 <0.05). The lowest amount is observed in shrub savannahs (3.62±0.57 tC / ha) in the first year and in the Logone-Chari (Table 3). In the wooded savannah according to the Departments, there is a highly significant difference (0.003 <0.01) between the Departments and the types of vegetation formation. In the Mayo-Dany (11.56±1.70 tC / ha) in the first year, carbon in the most important underground phytomass is found in Mayo-Sava (7.57±2.30 tC / ha) in the second year. The production of carbon in the subterranean phytomass according to department in the shrub savannahs is very low compared to the plant formations. There is a highly significant difference (0.003 <0.01) between Departments and types of plant formation. This quantity is much more common in Mayo-Danay (5.60±1.73 tC / ha) in the first year, the lowest in Mayo-Sava (3.56±1.15 tC / ha) in the second year. In protected areas, carbon in the root phytomaas produced is almost identical over the two years. Overall, the first year shows a slightly higher amount of carbon in the underground phytomass compared to the second year, whereas the statistical analysis shows that there is a very highly significant difference (0.000<0.001). In sacred forests, the amount of carbon in the root crop according to the Departments is very highly significant (0.000<0.001) between departments and types of plant formation. It is most important in the Mayo-Kani (13.11±1.73 tC / ha) in the first year and smaller in the Logone-Chari (8.22±2.29 tC / ha) in the second year. The carbon in root phytomass obtained in the protected areas according to the Departments has a highly significant difference (0.001 <0.01) between the departments over the two years. This quantity is higher in Mayo-Danay (12.95±3.44 tC / ha) in the first year and low in the Mayo-Kani (10.81±3.46 tC / ha) in the second year. The quantity of carbon varies according to the volume of the diameter of the wood and the number of individuals per hectare. The fluctuation of the amounts of carbon in the different types of plant formation is due to the fact that some are protected and others are left to the pressure of the riparian population.

Table 3. Differences in root carbon phytomass betweenvegetation types (tC/ha)

	WS	SS	SF	PA	PV
Year 2014					
MD	$11.56\pm1.70_{a}^{A}$	$5.60\pm1.73_{a}^{B}$	$11.86\pm2.29_{a}^{A}$	$12.95\pm3.44_{a}^{A}$	0.01*
MK	$10,57\pm1.71_{a}^{A}$	$5.28\pm2.3_{a}^{B}$	$13.11\pm1.73_{a}^{A}$	$11.25\pm3.44_{a}^{A}$	0.056*
MS	$7.81\pm2.30_{a}^{AB}$	$3.88\pm1.15_{a}^{B}$	$12.05\pm1.15_{a}^{A}$	$10.85\pm2.87_{a}^{A}$	0.03*
LC	$7.57\pm2.30_{a}^{B}$	$3.62\pm0.57_{a}^{C}$	$8.46\pm2.29_{b}^{AB}$	$12.76\pm3.44_{a}^{A}$	0.017*
PV	0.093ns	0.39ns	0.05*	0.10ns	PV
Year 2015					
	WS	SS	SF	PA	PV
MD	$11.32\pm1.73_{a}^{A}$	$5.48\pm1.73_{a}^{B}$	$11.93\pm2.3_{a}^{A}$	$12.89\pm3.46_{a}^{A}$	0.03*
MK	$10.70\pm1.73_{a}^{A}$	$5.41\pm2.3_{a}^{B}$	$13.09\pm1.73_{a}^{A}$	$10.81\pm3.46_{a}^{A}$	0.045*
MS	$7.83\pm2.3_{b}^{B}$	$3.56\pm1.15_{a}^{C}$	$12.04\pm1.15_{a}^{A}$	$10.96\pm2.88_{a}^{A}$	0.002**
LC	$7.60\pm2.32_{b}^{B}$	$3.73\pm0.57_{a}^{C}$	$8.22\pm2.29_{b}^{AB}$	$12.70\pm3.46_{a}^{A}$	0.042**
PV	2.94*	0.37ns	0.029*	0.1ns	

The numbers which have the same letters at the same column are not significantly differently at the top indicated.

The numbers which have the same letters at the same ling are not significantly differently at the top indicated.

WS= Wooded Savannah, SS= Shrub Savannah, SF= Sacred Forest, PA= Protected Area, MD= Mayo-Danay, MK=Mayo-Kani, MS=Mayo-Sava, LC=Logone-Chari, PV= p-value

G. Total carbon in the different vegetation types

The amount of total carbon varies significantly between years, Departments and vegetation formations (0.02<0.05). The total amount of carbon encountered in wooded savannahs is almost similar in terms of year. In the wooded savannah according to the Departments, there is a highly significant difference (0.003<0.01) between the Departments and the types of vegetation formation. Shrub savannahs have nearly identical total carbon content but are lower during the two years compared to other types of vegetation formation. Total departmental carbon production in shrub savannahs is very low compared to plant formations. There is a highly significant difference (0.003<0.01) between Departments and types of plant formation. This quantity is much higher in the Mayo-Danay (31.373 tC / ha) in the first year, the lowest in Mayo-Sava (18.918 tC / ha) in the second year (fig.5). In sacred forests, the total amount of carbon obtained varies slightly between years (0.01<0.05). In sacred forests, the amount of total carbon according to the Departments is very highly significant (0.000<0.001) between departments and types of plant formation and years. It is most important in the Mayo-Kani (80.239 tC / ha) in the first year and lowest in the Logone-Chari (47.801 tC / ha) in second year due to the transformation of Sacred forests in sacred houses. In protected areas, the total carbon produced is almost identical over the two years. The total carbon obtained in the protected areas according to the Departments has a highly significant difference (0.001<0.01) between the départements during the two years. This quantity is higher in Mayo-Danay (79.062 tC / ha) in the first year and very low in the Mayo-Kani (64.583 tC / ha) in the second year. This is explained by the fact that the Moundang, guiziga and Toupouri always have a sacred forest in their villages. They say that "our forests serve to protect us from plagues and epidemics, to practice the initiatory rites of boys at least to transform them into men." And therefore they deserve to be protected. The total quantity of carbon varies according to the volume of the diameter of the wood and the number of individuals per hectare. The fluctuation of the total amount of carbon in the different types of plant formation is due to the fact that some are protected and others are left to the pressure of the riparian population.

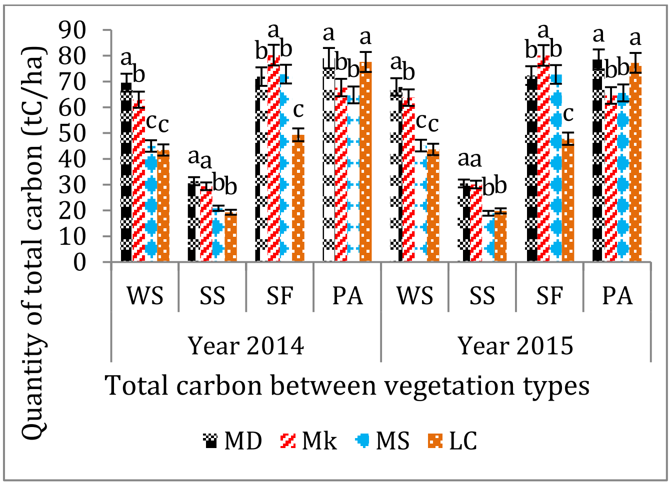

Figure 5. Differences in total carbon between vegetation types according to seasons (tC/ha)

The figures having the same letters are not significantly different at the shord of 0,50.

MD= Mayo-Danay, MK=Mayo-Kani, MS=Mayo-Sava, LC= Logone-Chari, WS= Wooded Savannah, SS= Shrub Savannah, SF= Sacred Forest, PA= Protected Area.

H. Quantity of emitted CO_2 between vegetation types according to years

The amount of carbon dioxide (CO_2) varies significantly between years, Departments and plant formations (0.02 <0.05). This amount encountered in wooded savannahs is almost similar according to year. In the wooded savannah according to the Departments, there is a highly significant difference (0.003 <0.01) between the Departments and the types of vegetation formation (Fig 6). The most important CO_2 is in Mayo-Danay (254.934 tCO_2 / ha) in the first year, the lowest in Mayo-Sava (159.249 tCO_2 / ha) in the first year. Shrub savannahs show an almost identical but lower amount during two years compared to other types of vegetation formation. The amount of CO_2 as a function of department in shrub savannahs is very low compared to plant formations. There is a highly significant difference (0.003 <0.01) between Departments and types of plant formation. This high value is much higher in Mayo-Danay (115.034 tCO_2 / ha) in the first year, the lowest in Mayo-Sava (69.367 tCO_2 / ha) in the second year. In sacred forests, the amount of CO_2 obtained varies slightly between years (0.01 <0.05). In sacred forests, this amount according to the Departments is very highly significant (0.000 <0.001) between departments and types of vegetation formation. It is most important in the Mayo-Kani (294.211 tCO_2 / ha) in the first year and smaller in the Logone-Chari (175.271 tCO_2 / ha) in the second year. The CO_2 obtained in the protected areas according to the Departments has a highly significant difference (0.001 <0.01) between the departments during the two years. This value is higher in Mayo-Danay (289.895 tCO_2 / ha) in the first year and very low in Mayo-Kani (236.805 tCO_2 / ha) in the dry and second year. The amount of CO_2 varies depending on the molecular weight of the plant and the number of individuals per hectare. The fluctuation of this value in the different types of vegetation formation is due to the fact that some are in areas defended and others are left to all the pressures of the riparian population. Our daily activities contribute strictly to climate change when land is converted for agricultural purposes and trees are destroyed, a new source of CO_2 emissions is created.

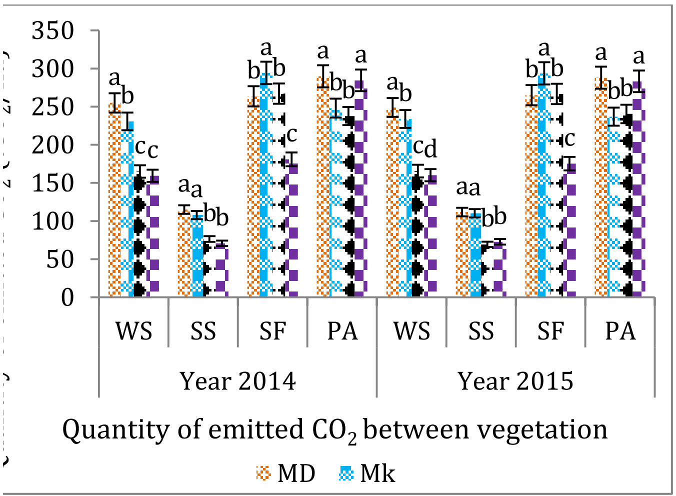

Figure 6. Quantity of emitted CO_2 between vegetation types according to year (t CO_2/ha)

The figures having the same letters are not significantly different at the shord indicated.

MD= mayo-danay, MK= mayo-kani, MS= mayo-Sava, LC= logone-chari, WS= Wooded Savannah, SS= Shrub Savannah, PA= Protected Area, SF= Sacred Forest.

G. Carbon credit between vegetation types according to year

The monetary value varies significantly between years, Departments and plant formations (0.02 <0.05). The carbon credit encountered in wooded savannahs is almost similar according to year. In the wooded savannah according to the Departments, there is a highly significant difference (0.003 <0.01) between the Departments and the types of vegetation formation (Fig. 7). The most important carbon credit is the Mayo-Dany (2549.337 Dollar / ha) in the first year, the lowest in Mayo-Sava (1592.486 Dollar / ha) in the first year. Shrub savannahs have an almost identical monetary value but are lower during the two years compared to other types of vegetation. The lowest amount is observed in shrub savannahs (1150.342 Dollars / ha) in the first year, the lowest is in the Mayo-Sava (693.665 Dollars / ha) in the second year. In sacred forests, the monetary value according to the Departments is very highly significant (0.000<0.001) between departments and types of plant formation and year. It is higher in the Mayo-Kani (2942.112 Dollars / ha) in the first year and lower in the Logone-Chari (1752.709 Dollar / ha) in the second year due to the transformation of Sacred forests in sacred houses. The carbon credit obtained in the protected areas according to the Departments has a highly significant difference (0.001<0.01) between the departments over the two years. This value is higher in Mayo-Danay (2898.949 Dollars / ha) in the rainy and first year and very low in the Mayo-Kani (2368.052 Dollar / ha) in the second year. The monetary value varies according to the volume of the diameter of the wood and the number of individuals per hectare. The fluctuation of this value in the different types of vegetation formation is due to the fact that some are well preserved and others are left to all the pressures of the riparian population.

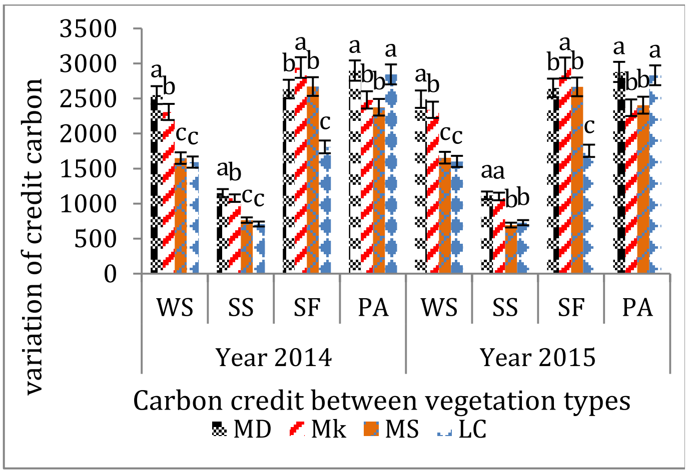

Figure 7. Differences in carbon credit between vegetation types according to years (Dollar/ha)

The figures having the same letters are not significantly different at the shord of 0,50.

MD= Mayo-Danay, MK=Mayo-Kani, MS=Mayo-Sava, LC= Logone-Chari, WS= Wooded Savannah, SS= Shrub Savannah, SF= Sacred Forest, PA= Protected Area.

I. Ascending hierarchical clustering of the quantities of total carbon

The ascending hierarchical classification of the total quantities of carbon sequestrated is constituted of 7 classes namely:

-The First class consists of 27 species: *Acacia ataxacantha, Acacia sieberiana, Annona senegalensis, Cadaba farinosa, Capparis fascicularis, Celtis integrifolia, Combretum* sp, *Commiphora africana, Dichrostachys cinerea, Diospyros mespiliformis, albida, Ficus abutifolia, Ficus gnaphalocarpa, Lannea acida, Maerua angolensis, Tamarindus indica, Ximenia americana, Ziziphus mauritiana, Maytenus senegalensis, Sclerocarya birrea, Grewia barteri, Bridelia ferruginea, Piliostigma reticulatum, Khaya senegalensis, Stereospermum kunthianum, Phyllanthus muellerianus, Lannea fruticosa*.

-The second class brings together 3 species: *Acacia hockii, Acacia polyacantha, Combretum aculeatum.*

-The third class contains 9 species: *Acacia nilotica, Acacia seyal, Acacia senegal, Acacia tortilis, Combretum glutinosum, Combretum nigricans, Terminalia glaucescens, Hexalobus monopetalus, Bauhinia rufescens.*

- The fourth group consisting of 26 species *Adansonia digitata, Albizia lebbeck, Bombax costatum, Boswellia dalzielii, Borassus aethiopum, Commiphora pedunculata, Dalbergia melanoxylon, Entada abyssinica, Ficus platyphylla, Gardenia aqualla, Grewia bicolor, Lannea schimperi, Lannea* sp., *Mitragyna inermis, Prosopis africana, Senna singueana, Steganotaenia araliacea, Sterculia setigera, Strychnos pinosa, Vitellaria paradoxa, Vitex doniana, Ziziphus abyssinica, Ziziphus spina-christi, Grewia senegalensis, Lonchocarpus laxiflorus, Senna siamea.*

-The fifth class is composed of 4 species: *Anogeissus leiocarpus, Balanites aegyptiaca, Feretia apodanthera, Piliostigma thonningii.*

-The sixth class is organized of 3 species: *Azadirachta indica, Combretum adenogonium, Combretum collinum.*

1) - The seventh class comprises a single species (Guiera senegalensis).

2) Hierarchical ascending classification (HAC) makes it possible to classify species by affinity. Where appropriate, species with similar quantities of sequestered Carbon are found in the same class and these species have moderately strong correlations.

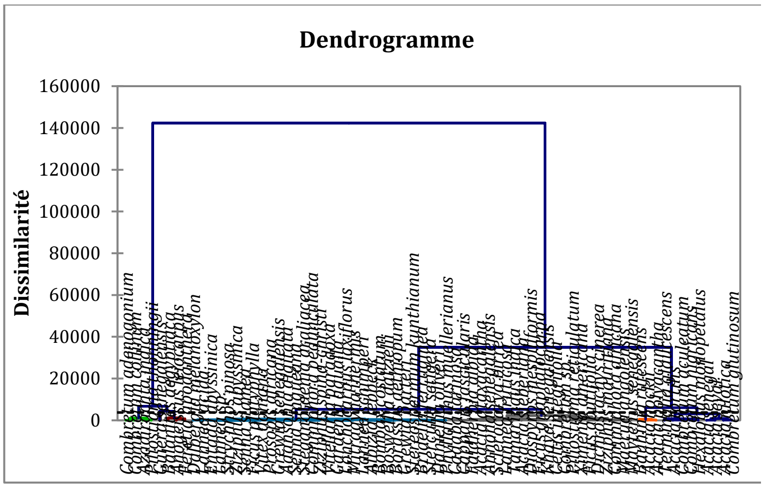

Figure 8 . Classification Ascendente Hierarchique

IV. Discussion

Quantification of the phytomass of the grass stratum in the different types of vegetation formation is much more observed in the Protected Areas of Mayo-Danay (0.697375 t / ha / year). However, shrub savannahs have very low levels of phytomass in the Logone and Chari (0.00033 t / ha / year). Thus, on the whole, protected areas, wooded savannahs and sacred forests are emerging from grasses such as *Loudecia* spp., *Hyparrhenia* spp., However, the animals there graze little when they are mature. It is in the shrub savannah that the animals apple and the herbaceous phytomass is clearly consumed. While in other types of training times access is prohibited to animals and the ph tomassage is considerable. These results are in agreement with those of [33] which showed that the natural formations protected or defended (T0) and weakly cut (T1) have a very marked phytomass (0.0076 t / ha / Year) and (0.0079 t / ha / year) dry weight. [9] and [11] have also shown in the same vein that grazing and bushfires tend to reduce accumulated grassy phytomass differently depending on their intensity, violence and period (early fires or late fires). The aerial phytomass of trees varies significantly between types of plant formations and years. Sacred forests in the Mayo-Kani have a large amount of phytomass (133.62±1.72 t/ha). The lowest phytomass is observed in the shrub savannahs (78.78±1.73 t / ha) of the Logone and Chari. These values have taken into account the DBH and the height of the trees, which justifies the greater quantity of biomass in the sacred forests to that of the shrub savannah because in the latter, it is observed that the twigs or the young feet in the Shrub savannahs due to deforestation causing vertiginous decline in biomass. To this problem is added the pressure of the cattle which damages the trees and shrubs. [19] showed that intense and continuous grazing in the sahelian environment reduces the floristic richness and density of trees and shrubs. Among the factors of the reduction of the phytomass in the savannah and of environmental degradation, the bush fires are not in rest. [24] mentions that systematic fires degrade the forest and those large trees disappear from the landscape; they are receding over the years, at the will of the repeated passage of the bush fires. These different pressures greatly reduce the diameter of the trees. The important quantity of the phytomass observed in these species is explained by the fact that the environment is favorable for their development and consequently these species possess very important trunks and heights. This is in agreement with [25] who explained that biomass in ecosystems is linked to the presence of large trees whose contribution to biomass is very preponderant. Incorporating height into the regression model can increase the potential for applicability of equations in different sites since height and DBH are often used as an index for increasing site conditions, it will also help explain [20], which have shown that the height and diameter at 1.30 m increase considerably the amount of phytomass of the trees. Thus the sacred rainforest forests in Mayo-Kani have a very high root biomass (23.13 t / ha). The lowest underground phytomass is observed in the wooded savannahs (15.13 t / ha) in the Logone and Chari. The large quantity observed in these species is explained by the fact that the environment is favorable for their development and that these species have developed techniques of adaptation to various environmental factors. The amount of carbon sequestered by species confirms the important role of wood in carbon sequestration. The amount of carbon obtained in the various species studied is between the interval (0.001 and 52.76 tC / ha). On the other hand, our values of the carbon amount of the species are less than the range 40-60 tC / ha given by [29]. The amount of carbon in the underground phytomass in the different types of plant formations is more represented in the Mayo-Kani sacred forests (24,189 tC / ha). The lowest root biomass is observed in shrub savannahs (6.685 tC /

ha) in Logone and Chari. The quantity of carbon varies according to the volume of the diameter of the wood and the number of individuals per hectare. The amount of root carbon in plant formations is higher than that of [1] (3.94 tC / ha) obtained in the wet savannas of Ngaoundere. The large amount of phytomass observed in these species is explained by the fact that these species are very dense in this environment and that these species have developed adaptation techniques. The total quantity of carbon is much more represented in the sacred forests of Mayo-Kani (80.239 tC / ha). This is explained by the fact that the Moundang, Guiziga and Toupouri always have a sacred forest in their villages. They say that "our forests serve to protect us from plagues and epidemics, to practice the initiatory rites of boys at least to transform them into men." And therefore they deserve to be protected. The lowest amount of total carbon in the shrub savannahs of Logone and Chari (18.918 tC / ha) is significantly lower than that of other types of vegetation formation. Overall, the total amount of carbon obtained in each type of vegetation form is greater than that of the Sudanian savannas of Angola (50 tC / ha) except in the shrub savannahs of Logone and Chari and Mayo-Sava. These findings in protected areas and sacred forests are almost similar to the amount of carbon reported by [17] and [22] who have shown that wooded and shrubs savannahs store an amount of carbon sequestered in the periurban vegetation of Ngaoundéré close to 154.868 tC / ha / year and [33] which had also obtained 169.90 tC / ha in the periurban savannah of Ngaoundéré. The large total amount of carbon in these species can be explained by the fact that they are very abundant in the environment. The statistical test indicates the existence of a significant difference between the values of the species ($p < 0.05$). The largest monetary value is obtained in the Sacred Forests of Mayo-Kani ($2942.112 / ha). The lowest is observed in the wooded savannahs ($ 693.665 / ha) of the Logone and Chari. These low monetary values could be explained by the fact that shrub savannahs are left open to all actors of deforestation because they are not protected and they are very close to the villages. On the other hand, the analysis of the variance reveals the existence of a significant difference between the four types of plant formations and between the seasons (0.000 <0.05). The monetary value assessed by the species confirms the important role of trees in the savannah. It is obvious that if the sustainable management of the vegetation of the Sudano-Sahelian zone was applied, it possessed enormous natural potentialities. Thus, given their value to local populations and their role in mitigating and adapting climate change, it is important to sustainably manage these natural resources. The amount of carbon dioxide (CO_2) that would be emitted into the atmosphere if the trees inventoried in the four types of vegetation formations studied were slaughtered and burned completely. The largest amount of CO_2 was observed in the Mayo-Kani Sacred Forests (294.211 tCO_2 / ha). The lowest amount of CO_2 was observed in the shrub savannahs of Logone and Chari (69.367 tCO_2 / ha). Our daily activities contribute strictly to climate change when land is converted for agricultural purposes and trees are destroyed, a new source of CO_2 emissions is created. It is necessary to moderate the abusive cuts and to protect the plants under the tooth of the machetes, axes and others to hope to reduce the emissions of CO_2. It is therefore necessary to know how to moderate the most abusive and illicit cuts, even the skimming of the finest timber, are less serious for the planet than the clearing and retreat of the bush in favor of agriculture, urbanization which weakens the grounds. Yet vegetation is unavoidable for the life of man on earth: it protects the soil against the sun's rays and the impact of rain; Their leaves form the humus and recycle the mineral elements; The leaf litter protects the soil their roots work the soil, improve water infiltration, retain the soil and can pump the mineral elements from the deep layers of the soil.

V. Conclusion

Sequestration and carbon credit in the Sudano-Sahelian zone of Cameroon vary from one department to another, from one year to another, from one plant formation to another. The quantity of carbon sequestered in the rainy season is slightly higher than that of sequestration in the dry season, so the quantity of the aerial phytomass is considerably superior to the phytomass of the roots. Sacred forests and protected areas have a gigantic potential for carbon sequestration. The amount of herbaceous phytomass is higher in the Mayo-Danay protected areas (0.496625 t / ha / year) and very low in the Logone and Chari shrub savannahs (0.00051 t / ha / year). The amount of total sequestered carbon is high in the Mayo-Kani sacred forests (80.239 tC / ha) but low in the shrub savannahs of Logone and Chari (18.918 tC / ha). The highest monetary value is obtained in the sacred forests of Mayo-Kani ($ 2942.112 / ha). The largest amount of CO_2 was observed in the Mayo-Kani sacred forests (294.211 tCO_2 / ha), the lowest in Logone and Chari shrub savannahs (69.367 tCO_2 / ha). Reforestation in the Sahel combines very well with the fight against poverty, as forestry productions have a very important impact on the economies of the population. In addition, species better suited to arid climates provide potentialities in terms of wood, carbon sequestration and non-wood crops. These potentialities are expressed in monetary terms so as to be easily compared with each other and with other sources of income of the populations.

VI. ACKNOWLEDGEMENT

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