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Full Length Research Paper

Impact of wood logging on the phytomass and carbon sequestration in the guinea savanna of Ngaoundéré, Adamaoua Region, Cameroon

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Abstract

The present study estimated the impact of wood loggings on the phytomass production and carbon sequestration in the guinea savanna of Ngaoundéré, Adamaoua Region, Cameroon. The results showed that the phytomass of arborescent savanna is more important (169.91 t.ha^{-1}.year^{-1}) than that of the shrubby savanna (49.18 t.ha^{-1}·year^{-1}). The sequestration of carbons correlated positively with phytomass (r= 0.98, P = 0.05). The very strong wood loggings (T3) are at the origin of the decline of phytomass production (36.53 tc.ha^{-1}.year^{-1}) and of the sequestration of carbons (17.17 tc.ha^{-1}.year^{-1}) in these savannas. These values are indicators of degradation of the outer-urban savannas in Ngaoundéré. The State government and the local population should jointly embark on the management for the protection of savannas in the Region.

Keywords: Wood logging, phytomass, carbon, sequestration, guinea savannas, Adamaoua.

INTRODUCTION

The challenge of the climatic change requires efforts from the whole local and international communities. Cameroon, particularly conscious of the stakes of this phenomenon, is resolutely engaged to support the durable development. Within the framework of the negotiation of Copenhagen for the fight against the climatic change, the effort must be directed for the maintenance of the increase in the average temperature of the sphere in the side of 2°C compared to the pre-industrial level by limiting to the maximum the level of carbon emission in the atmosphere. The only durable solution is to delimit deforestation and to encourage the reforestation and the durable management of the grounds. However in savannas, the deforestation of the wood loggings becomes extensively alarming these recent years. The deforestation of savannas due to the intensive wood loggings today is estimated at 154,000 km^2/year (Aldhous, 1993). This leads to the emission of more than 0.32 Gt of carbon in the atmosphere (Kotto-samé*et al.,* 1997). Very few studies were carried out on

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the sequestration of the carbon in tropical Africa. Studies conducted by Kotto-Samé *et al*. (1997) are the most known. On the other hand, works were made in the United States on the carbon held in the agriculture (Krcmar, 2001) and in the natural environment (Jacinthe et *al.,* 2002). Other authors were interested in the carbon held in the ground (Dolman *et al*., 2002; Vann den By gaart *et al.,* 2002). Between 1850 and 1998, 270 Gt of carbon was emitted from the industries, with 176 Gt accumulated in the atmosphere and 120 Gt stored in the oceans (McCarty and Ritchie, 2002). During this period, the use of lands by man pulled a broadcast of about 136 Gt of carbon in the atmosphere. Forests are more important, because they hold carbon faster than the other ground circles. Krcmar (2001) showed that one m^3 of wood store approximately 200 kg of carbon. He also asserted that one ton of carbon held in the forest biomass corresponds to 3.667t of carbons removed from the atmosphere. The carbon is a good indicator of the fertility of the soil and it is found, in the form of organic matter, it also increases the soil quality and improves the capacity of regulation of water and the atmosphere of the soil, by improving its structure, its capacity of water retention, its reserves in nourishing elements, its biodiversity as well as the depth of implanting of plants which grow therein (Lal *et al*., 2002). The vegetation generally and the forests in particular play an essential role in the global cycle of carbon by storing in the long term an important quantity of carbon in the biomass and in the soil. Forests cover approximately one third of the continents' surface (Kramer, 1981) and they make approximately two thirds of the global photosynthesis (Watson *et al*., 1990). The forest ecosystems store generally 20 - 100 times more carbon by unity of surface than farmlands (Ciesla, 1997). On the other hand, their soils, which contain about 40% of the total carbon, are of a major importance during the consideration of the management of forests. The destruction of forests and woody regions can have as consequence a big loss of carbon in the atmosphere (Wang *et al*., 2002), engendering, a degradation of the quality of soils, reduction of the phytomass which is the dry biomass and the sequestration of carbons. The phytomass is a key structure variable for research into ecosystem dynamics and it is defined as the net amount of energy fixed by plants (Terradas, 2001). In the outer-urban zone of Ngaoundéré, the destruction of the vegetation by wood logging led to an increase of the cultivable surfaces from 120 ha in 1951 to 1,256 ha in 2001 with an increase rate of 22 ha/year (Tchotsoua, 2006). The direct consequence of the decline of plant production is felt on the heating of the earth, the change of the precipitation and the increase in temperature in the outer-urban zone of Ngaoundéré. In Ngaoundéré, studies on the stock of carbon in shrubby and arborescent savanna was conducted by Ibrahima and Habib (2008), but there is a dearth of data on carbon stock on the types of woods' logging, the woody savannas, the seasons and some parameters of phytomass (production of useful wood, herbaceous phytomass, the litter and the residues of the litter). Thus, the study aimed at knowing the impact of wood loggings on the production of phytomass and sequestration of carbons in the guinea savanna of Ngaoundéré, Adamaoua Region, Cameroon.

MATERIALS AND METHODS

Study area

The study was undertaken in ten (10) villages namely: Béka Hooseré, Onaref, Wakwa, Tizon, Beskewal, Ngaohora, Borongo, Dang, Darang and Mban-Mboum all located in the Ngaoundéré district of the Adamaoua Region, Cameroon (Figure 1). These villages are located at about 10 km for the shortest and 60 km for the farthest distance from Ngaoundéré the capital city of Adamaoua Region, Cameroon. Ngaoundéré is located at latitude 7° 19' N and longitude 13° 34' E. Its population was estimated at about 230 000 inhabitants in 2001 (Tchotsoua, 2006) with an increase rate of 2.81 % per annum. The main ethnic groups are the Fulbés, Mbororos, Gbayas, Mboums, Dourous, Yemyems, Hausas, and the Koutinés. The economic activities of the local inhabitants are mainly animal husbandry and land farming. The soil of the area belongs to the geo-morphological domain of the plateau of Adamaoua. They are characterized by sedimentary, volcanic, granitic and metamorphic rocks. The vegetation of the Adamaoua corresponds to a typical Sudano-guinea savanna constituted with shrubby, arborescent and woody savannas. The precipitations are maximal in August and practically null from November to February. The hygrometric is maximal in August with a monthly average humidity of 81.38 %.

Choice of the different wood logging zones in the guinea savannas of Adamaoua Region, Cameroon

To choose the different wood logging, interviews were conducted with group of persons. The prospections with the population in the site were made. The types of wood logging in the savannas depended on the degree of accessibility to the site (absence or proximity to easy access road), the distance to the village (0-0.5 km, 0.5-1 km, 1-2 km, 2-4 km, 4-6 km, > 6km) and the percentage of the wood cut. At the end of prospection, four types of wood logging were selected:

- Pilot or witness logging (T_0): made up with natural formation where the estimated percentage of wood logging is less or equal to 10 %. They are generally

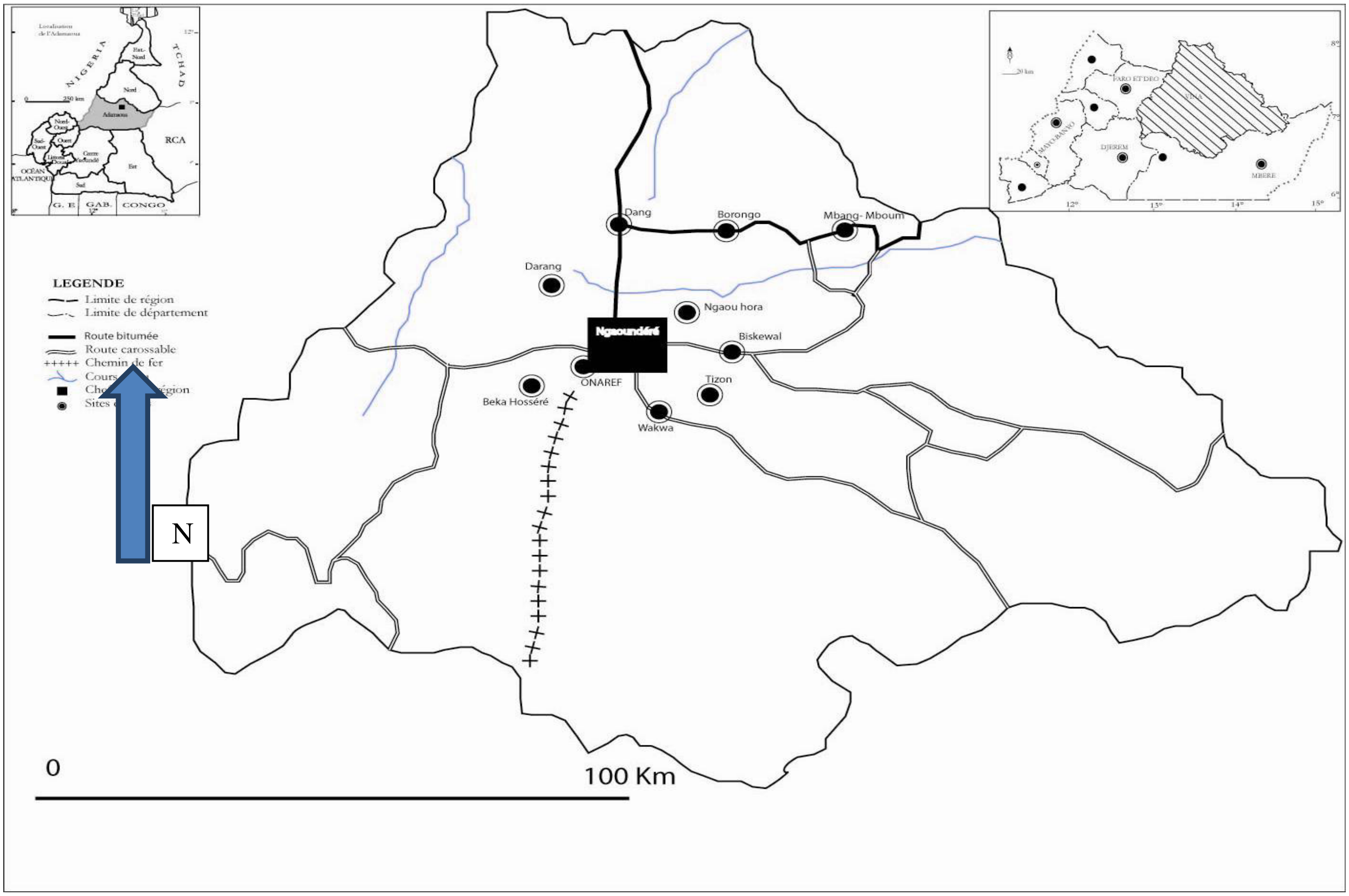

Figure 1. Map of study area

protected areas by the inhabitants;

- Weak logging (T_1): vegetation where the percentage of wood logging is between 11 and 25%;
- Average logging (T_2): vegetation where the percentage or wood logging is between 26 and 50%;
- Complete or total logging (T_3): vegetation where more than 50% of woods are cuts.

Experimental Design

The study was a split-plot design with 3 factors (shrubby savanna, arborescent savanna and woody savannas) (Table 1). The pieces were numbered from 1 to 12, delimitated by numbered cement terminals or wood stakes. One hundred and twenty sites (3 types of savannas × 4 types of cuts × 10 villages) were selected with 30 sites for each treatment.

Measure of the vegetation phytomass

The measure of the vegetation phytomass was obtained by determination of the biomass of the different plant formations. The measures of the biomasses were made at the height of the rainy season (June to September), the beginning of dry season (October to December) and at the height of the dry season (January to March) during three years in the quadrats of 10 x 10 m. The measure of the biomass of shrubs (size lower than 2 m) was realized according the method of Kotto-Samé *et al.* (1997) and Mbolo (2005). The quandrants and right angles of the plots of land were measured using a decameter and a set square respectively. In every site, five quadrants (10m x 10m) were retained to know the biomass of the ligneous flora affected by man inorder to estimate the risk which this degradation can cause on the vegetation, in the survival of the man and the animal. In all 120 sites, 600

Table 1. Experimental design.

S/No	Villages									
	DAN	BEK	ONA	BOR	WAK	TIZ	NGA	BES	DAR	MBA
1	SbT2	SaT3	SbT0	SaT3	ScT1	SaT0	SaT0	SaT2	ScT1	SbT2
2	SbT3	SaT0	SbT1	SaT2	SbT0	ScT2	ScT0	ScT2	SbT0	SbT1
3	ScT3	SbT3	SaT2	ScT0	SaT0	ScT0	ScT3	ScT3	SbT2	SaT1
4	ScT1	ScT2	ScT1	ScT0	ScT3	SbT2	ScT3	SaT3	SbT2	ScT3
5	SaT2	ScT1	SaT3	ScT1	SaT1	SaT3	ScT2	SbT0	SbT1	SbT3
6	ScT3	SbT1	SaT0	SaT0	SaT1	ScT0	SaT0	ScT2	SbT0	SbT3
7	SaT1	SbT3	SaT1	SaT3	ScT2	SaT2	SbT1	ScT1	SbT1	SbT3
8	SbT1	SbT0	SbT1	SbT3	ScT1	SbT1	SbT3	ScT0	ScT3	SaT2
9	SaT2	SaT3	SaT1	SaT2	ScT0	ScT0	ScT2	ScT3	ScT2	ScT0
10	SbT2	ScT0	SaT1	ScT3	SbT1	SaT1	SbT0	SbT3	SaT0	ScT2
11	ScT2	SaT0	SbT3	SbT0	SbT2	SaT0	SaT2	SaT1	SbT0	SbT2
12	SaT2	SbT0	SbT1	SbT3	SaT0	SbT2	SaT1	SaT3	SaT3	ScT1

Keyword: BES: Beskewal; BEK: Beka; ONA: ONAREF; BOR: Borongo; WAK: Wakwa; TIZ: Tizon; NGA: Ngaouhoura; DAR: Darang; DAN: Dang; MBA: Mbang-Mboum; Sa: shrubby savannas; Sb: raised savannas; Sc: wooded savannas.

samples of 100 m^2 each were retained. The scientific names of all the species, their diameter to15 cm above the ground and their heights, their area surfaces and the numbers of the individuals by species were registered.

To determine the biomasses of shrubs, we proceeded to the systematic cutting of these shrubs between 0 to 5 cm from the ground by means of machetes and they were separated species by species. A fraction of 10 kg of these samples was taken to the steam room of the University of Ngaoundéré for the drying and the determination of the Total Dry Mass (TDM). The Total Dry Mass (TDM) was calculated according to the following formula:

TDM = 100 x TDT/ (100+Y), where TDT is the Total Dampness Mass and Y the moisture content. Y = (DM-DM)/DS) x 100, where DM is the Dampness Mass and DS the dry mass of the sample. The coefficient of the relationship between the dry weights over the weight of samples was calculated and used to estimate the phytomass of shrubs in the various plant formations according to the types of wood loggings. This phytomass was then expressed in ton per hectare per year ($t.ha^{-1}.year^{-1}$). The biomass of the big trees (size upper to 2 m) was estimated indirectly on the same plots of land by using an allometric model taking into account the parameters of the tree such as the DHP and the height. The equation of Anderson and Ingram (1993) was used to estimate the biomass because it was developed in the climatic conditions where the annual average rainfall varied between 1500 and 4000 mm thereby including that of Adamaoua which is between 1200-2000 mm.

The equation is as follows: B (kg) = exp. (3.114+0.9719 Ln (D^2H)), where B is the biomass of trees in kg, D the diameter DHP and H the height of the tree. The height of the big trees was estimated by clinometers.This was used to measure the vertical angles and estimate the heights of these big trees. With the help of clinometers, the contact point of the tree with the ground aimed at obtaining the angle $ß_1$. The angle $ß_2$ is obtained by aiming at the summit of the tree's base. The distance d is determined by measuring the gap which separates the observer from the tree. The height was determined by the Tangent (ß) = h/d, where h is the opposite side, d the adjacent side and ß the considered angle. The total height is defined by the sum of the heights: $H_t = h_1+h_2$. The biomass of trees was then expressed in ton per hectare per year ($t.ha^{-1}year^{-1}$).

The coefficient of the ratio dry weight overdamp weight within the framework of the phytomass of shrubs was applied to the biomass of trees to determine the exact value of the phytomass of trees.

Measure of the subterranean phytomass

The subterranean biomass was estimated in the same plots. Blocks of grounds of 625.10^{-5} m^3 (0.25 m x 0.25 m x 0.10 m) and 9375. 10^{-6} m^3 (0.25 m x 0.25 m x 0.15 m) were extracted at two deep levels: 06-10 cm and 10-25 cm. These weighed blocks, were sieved with a sieve having1mm stitch, then roots were manually sorted out and separated in two classes according to their diameters (Vogt *et al*., 1991). The fine roots (<2 mm) and small roots (included between 2 and 5 mm) were separated. These two groups were then weighed. Before the sieving, one sub-samples of ground was taken and weighed to calculate its moisture content and its apparent density. These sub-samples were returned to the laboratory to be dried at 60°C in the autoclave for 48 hours until a constant dry mass was obtained. The moisture content was calculated as previously. From the total dry mass of the samples of the ground, the visible density of the ground (D) was calculated as follows: $D = STD/(L^2 x\ h)$, where L is the side of the block of the ground (25 cm) and h is the height of the block of the ground or the depth of the hole (10 or 15 cm). It was expressed in kilogram per cubic meter ($Kg.\ m^{-3}$) then transformed to $t.\ ha^{-1}.year^{-1}$.

Measure of the production of useful wood

We call useful wood any cut and available wood on the ground in the savanna by man, animals, derooting or by other climatic factors and ready to be used for firewood orusage. This was realized by a team of three persons collecting systematically died trees on a surface of 50 x 50 m. These stored woods were classified by category of diameter and weighed on the spot by means of a portable weighing balance. The production of useful wood has been evaluated in the 120 parcels under the 4 conditions (T_0, T_1, T_2 and T_3). A team of three persons collected woods cut down by animals, people, wind and water. These woods were classified as function of the diameter and weighed. A fraction of 10 kg of each category was dried and the weight of the whole sample evaluated.

Estimation of wood logging in savannas

We took into account origins of wood logging. The diameter and the height of every cut stalk were measured from the ground. This allowed us to estimate the volume of cut stumps for the whole vegetation. We considered 90 % of these volumes as the part used by the local population for fire wood and usage.

Quantification and loss of the herbaceous phytomass in the different type's ofsavannas

The production of the herbaceous phytomass was measured during three years. To estimate this phytomass, 5 small places of 1 x 1 m on an area of 10 x 10 m were measured by means of a ribbon meter. The measures were systematically realized in the intersection of two diagonals of each plot of land of 10 x 10 m. Twenty (25) small places by hectare were held as replication that is a total of 1,600 small places of 1x1 m^2. The fresh biomass was collected and in continuation dried in the autoclave at the University of Ngaoundéré and then weighed. The loss of herbaceous phytomasswas estimated at 10 %.

Quantification of the litter and residues of the litter

The litters of shrubs and big trees were collected on 10 feet chosen at random on elementary surfaces of 1x1m^2 in the plots of land of 50 x 50 m. Samples, collected during the period of maximal production of the litter (October to February) were sorted out to free diverse fragments (representing 10 % of the litter).

In all 1,200 samples were collected, dried in the steam room and weighed with a precision weighing balance.

Evaluation of the total phytomass of savannas

The total phytomass was established by the air and sub-terranean phytomass of shrubs and trees, useful wood and cuts, herbaceous phytomass and by the litter.

Carbon sequestration in the savannas

Sequestration of epigeic carbon

For the shrubs, carbon sequestration was estimated as follows: $QCv = (TDM \times C)/100$, where, QC is the quantity of sequestrated carbon (t/ha/year); C = concentration in carbon. The value of carbon concentration (45 %) was used (Kotto-Samé *et al*., 1997). For big trees, the allometric equation of Brown*et al*. (1989) and Gauquelin *et al*. (1995) were adopted: $Y = 38.4908-11.7883 \times D +11926 \times D^2$, where Y = biomass ($t.\ C\ ha^{-1}$), D = DPH; $R^2 = 0.78$ was adopted.

Sequestration of hypogeic carbon

For shrubs with small roots, the carbon was estimated as follows: $QCs = (D \times C \times d)/100$; where QCs is the quantity of soil carbon, d the depth of the soil, D the apparent density of soil, C the concentration of the soil. For big trees with big roots, the weights are calculated according to the following formula: $Wr = 0.2464\ (D^2H)^{0.775}$, Wr (kg), where D is the diameter (cm) and H the height (m).

Data Analysis

Data were analysed using statigraphics and excel. The Duncan Multiple Test was used for the separation of means on the quantification of phytomass and useful woods of the savanna.

XL stat used to analyse of the principal component.

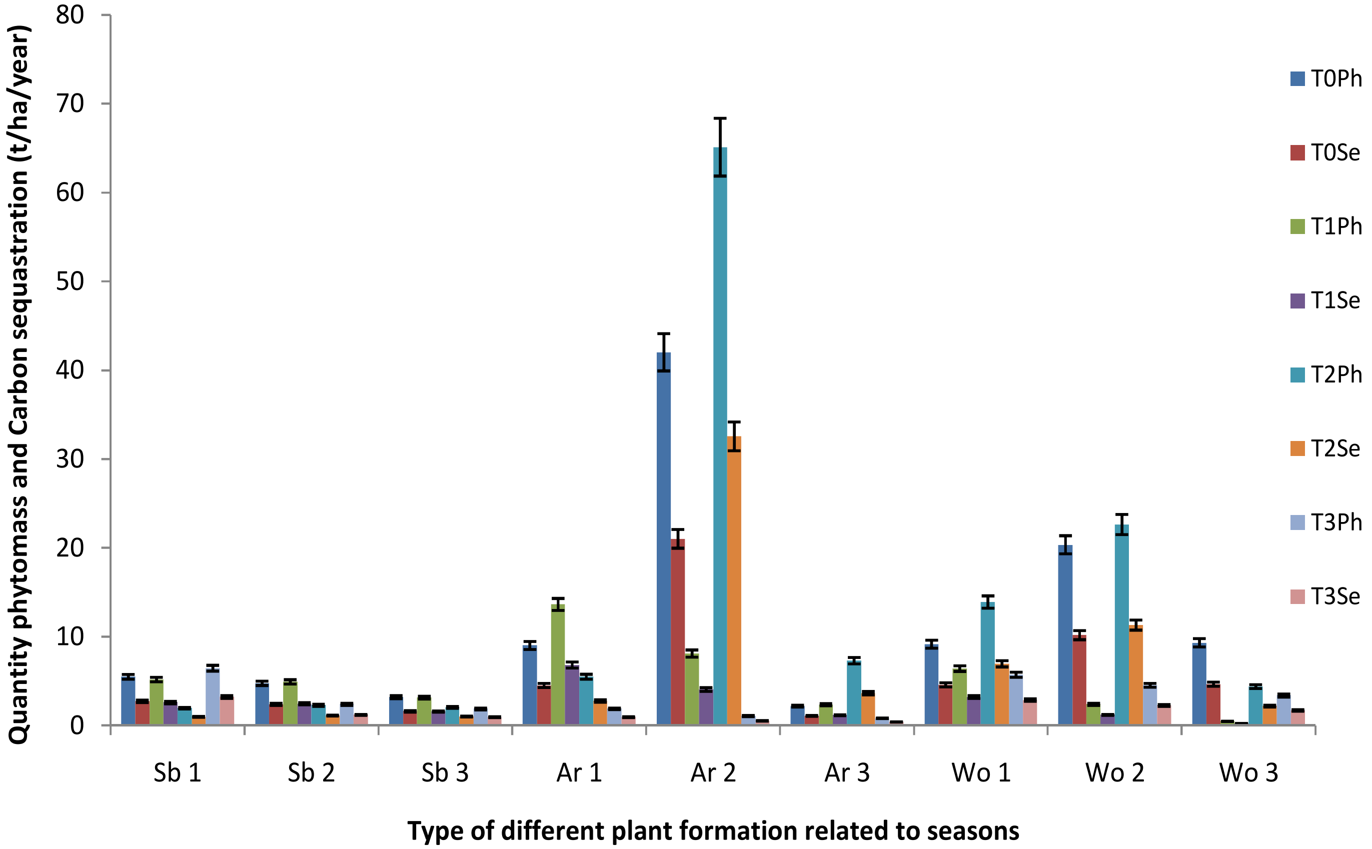

Figure 2. Phytomass and carbon sequestration of trees in relation to different types of wood loggings and season in the guinea savanna of Ngaoundéré, Adamaoua, Region, Cameroon

Keysword: numerals on the X-axis means:1=full rainy season (June - October); 2= beginning of dry season (November - December); 3= full dry season (January - March); Sb= shruubysavanna; Ar=arborescent savanna; Wo=woody savanna

T0P: control; T1Ph: weak wood looging; T2Ph: average wood logging; T3P : high wood logging,

Ph= Phytomass; Se= carbon sequestration.

RESULTS

Phytomass and carbon sequestration of trees in relation to different types of wood loggings and seasons

The phytomass of the three savannas (shrubby, arborescent and woody) in relation to the different types of wood loggings and seasons was presented in Figure 2.

The phytomass of the ligneous decreased drastically from 19.08 tha^{-1} year^{-1} at the peak of the rainy season (June to October) to 10.25 t. ha^{-1}year^{-1} at the peak of the dry season (January to February) in shrubby savanna. In arborescent savanna these values varied from 30.03t.ha^{-1}year^{-1} at the peak of the rainy season to 12.64 t ha^{-1} years-^{1} at the peak of the dry season. Likewise, the phytomass decreased drastically from 35 t.ha^{-1}year^{-1} to 17.57 t.ha^{-1}year^{-1} respectively in the rainy season to the dry season in woody savanna. There was a perfect correlation between phytomass and sequestration of carbon ($r = 0.98$, $p<0.05$).

Global production of the phytomass and carbon sequestration in different plants formation

Figure 3 represents the annual global balance sheet of the phytomass and carbon sequestration of the outer-urban savannas of Ngaoundéré in relation to wood loggings.

The phytomass of shrubs savannas, arborescent and wood savannas are respectively 49.18 (t.ha^{-1}year^{-1}), 169.91 (t.ha^{-1}year^{-1}) and 110.42 (t ha^{-1}year^{-1}). The distributions of phytomass are function of the various wood loggings in the different plants formations. They are respectively of the order of 109.25 t ha^{-1}year^{-1}and of 36.53 t ha^{-1}year^{-1}for control (T_0) and very strong loggings (T_3). With the eight parameters of production of the

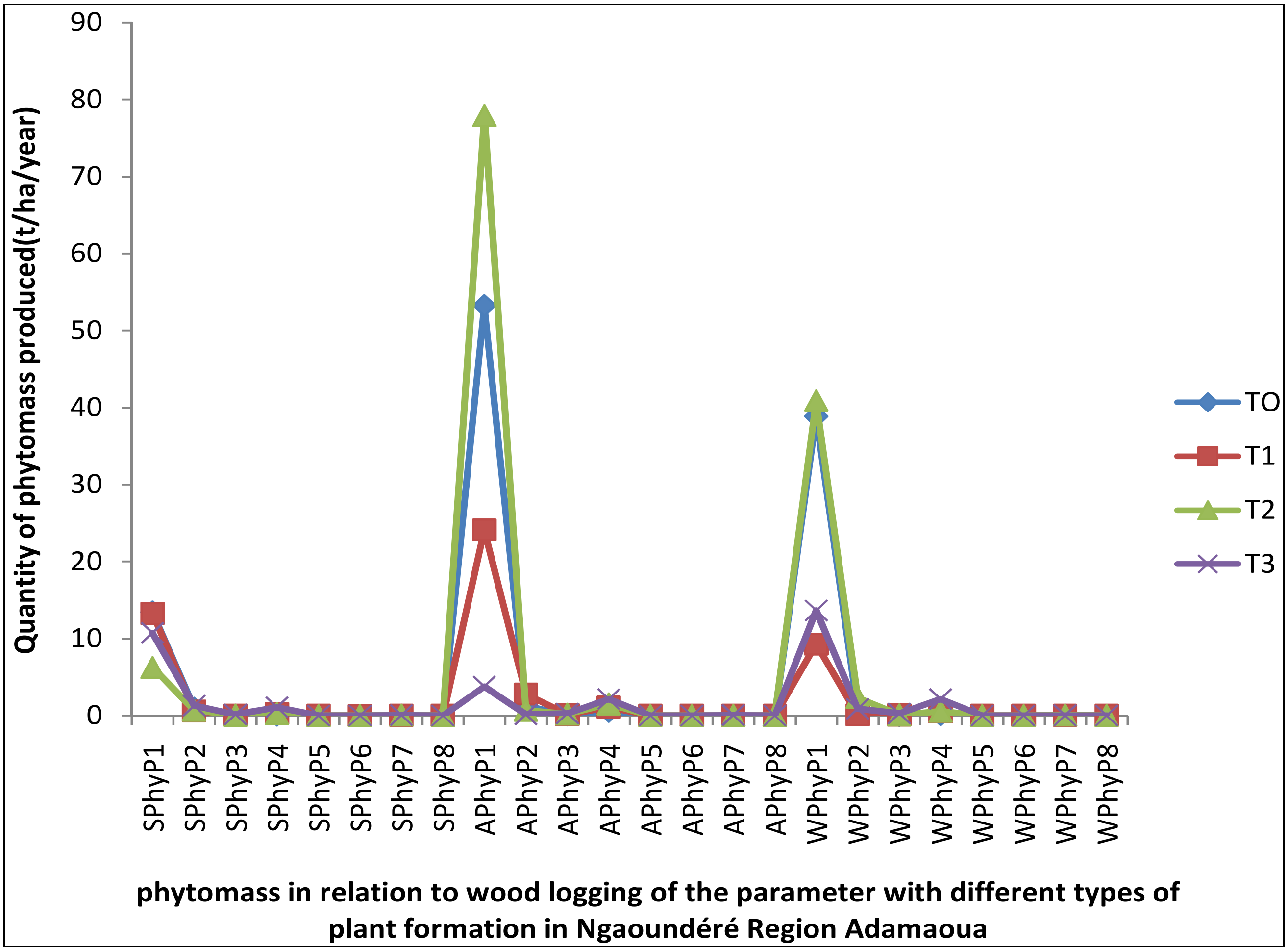

Figure 3. annual global balance of the phytomass in the guinea savanna of Ngaoundéréin relation to wood loggings.
Keys: Paremeters of phytomass production: P_1: phytomass of woods; P_2: Phytomass of useful woods; P_3: weight of cut stumps; P_4: loss of stem. P_5: herbaceous phytomass. P_6. Loss of herbaceous phytomass. P_7: litter phytomass and P_8: mass of the residue of the litter.
T_0: control; T_1: weak cut; T_2: mean cut; T_3: high cut, SPhy: phytomass shrubby, APhy: Phytomass arborescent, WPhy: phytomass woody.

savannas' phytomass , we realized that the phytomass of shruby savanna (49.18 t ha^{-1}year^{-1}) is lower than that of the arborescent (169.905 t ha^{-1}year^{-1}) and woody savanna (110.42 t ha^{-1}year^{1}). The carbon sequestration in the three types of savannain relation to the types of wood loggings is presented in Figure 4. The shrubby, arborescent and woody savannas produce the following quantities of trapped carbon: 23.12 tC ha^{-1}year^{-1}; 79.86 tC tha^{-1}year^{-1}and 51.90 C t ha^{-1}year^{-1}respectively in the nature. With regards to the types of wood loggings, the very strong wood logging held the lowest quantity of carbon sequestrated (17.17tC ha^{-1}year^{-1} than the control (51.35tC tha^{-1}year^{-1}), average (61.81C t ha^{-1}year^{-1}) and weak wood loggings (24.54tC ha^{-1}year^{-1})

Table 2 shows the minimum, maximum, mean and standard deviation of phytomass and sequestration of carbon in relation to wood logging. No variation was observed on the minimums of both phytomass and carbon sequestration in all types of wood loggings, but there were variations on the maximums of both phytomass and carbon sequestration. A positive correlation was also observed between mean and standard deviation of the phytomass and the carbon sequestration respectively

Analysis of the principal component using the Matrix of Pearson (n-1) showed a perfect correlation between T_0 and T_2 (R = 0,979), while a weak correlation was obtained between T_2 and T_3 (R =0,523). The biplot (axis F1 and F2) had a high relation with 97, 25 %**.** On the horizontal axis, F_1 has high correlation (83.69%) between the different plants formations while on the vertical axis F_2 had 13, 56 %. On the vertical axis, the phytomass and carbon sequestration in the different formations are clustered around of the axis (Figure 4).

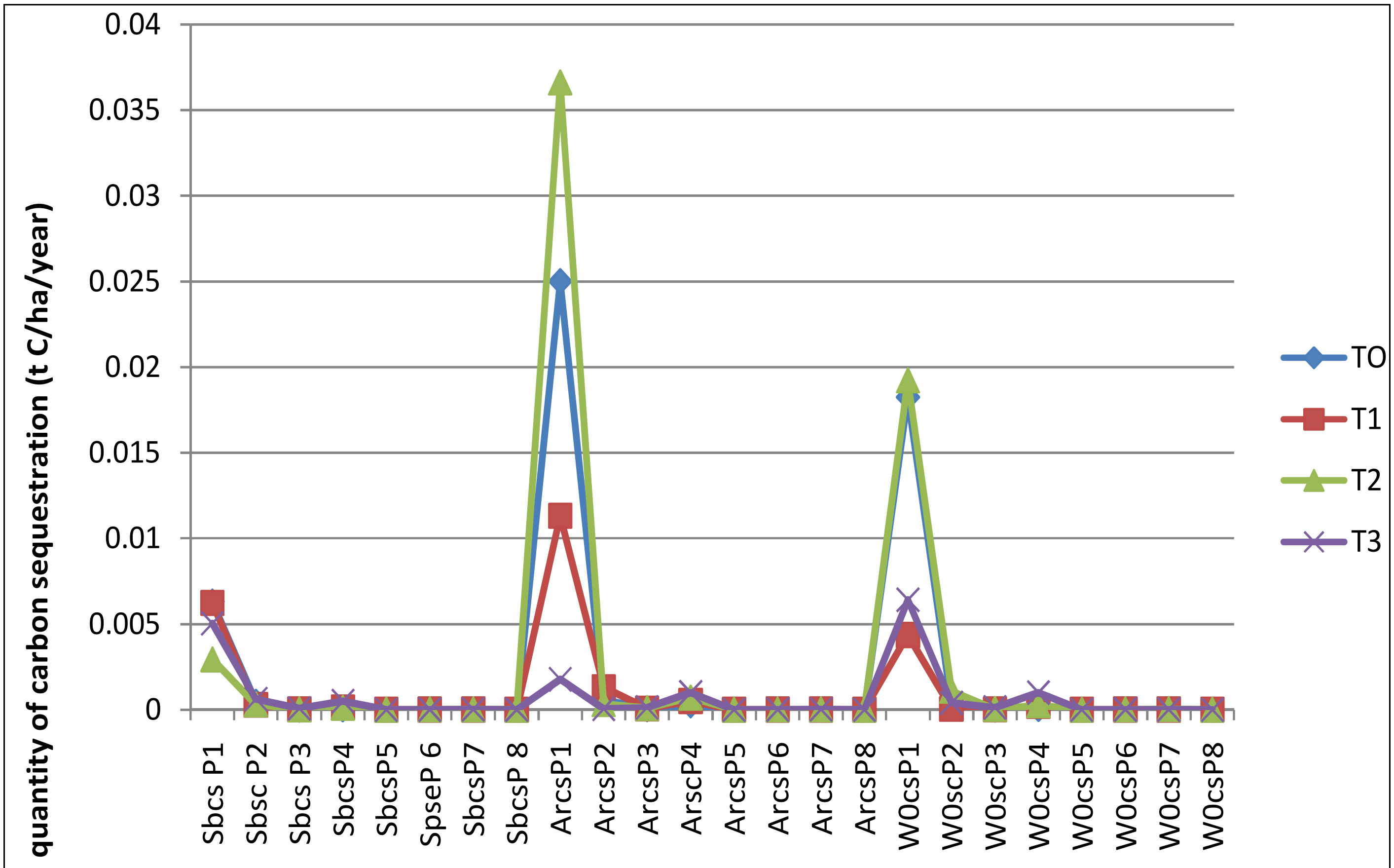

Figure 4. Annual global balance of carbon sequestration in the guinea savanna of Ngaoundéré in relation to wood loggings

Keys: Parameters of carbon sequestration production: P_1: phytomass of woods; P_2: Phytomass of useful woods; P_3: weight of cut stumps; P_4: loss of stem. P_5: herbaceous phytomass. P_6. Loss of herbaceous phytomass. P_7: litter phytomass and P_8: mass of the residue of the litter.

T_0: control; T_1: weak cut; T_2: mean cut; T_3: high cut, Sbse: carbon sequestration in shrubby savanna, Arse: carbon sequestration in arborescent savanna, W0se: carbon sequestration in woody savanna.

Table 2. Minimum, maximum, mean and standard deviation of phytomass and sequestration of carbon in relation to wood logging

Types of wood logging	Minimum Phytomass	Maximum Phytomass	Mean Phytomass	SD Phytomass	Minimum Sequestration	Maximum Sequestration	Mean Sequestration	SD Sequestration
T_0	0,010	53,230	4,555	13,232	0,001	25,018	2,141	6,219
T_1	0,000	24,080	2,178	5,663	0,001	11,318	1,024	2,661
T_2	0,000	77,920	5,482	17,535	0,001	36,622	2,577	8,241
T_3	0,000	13,650	1,525	3,443	0,001	6,416	0,717	1,619

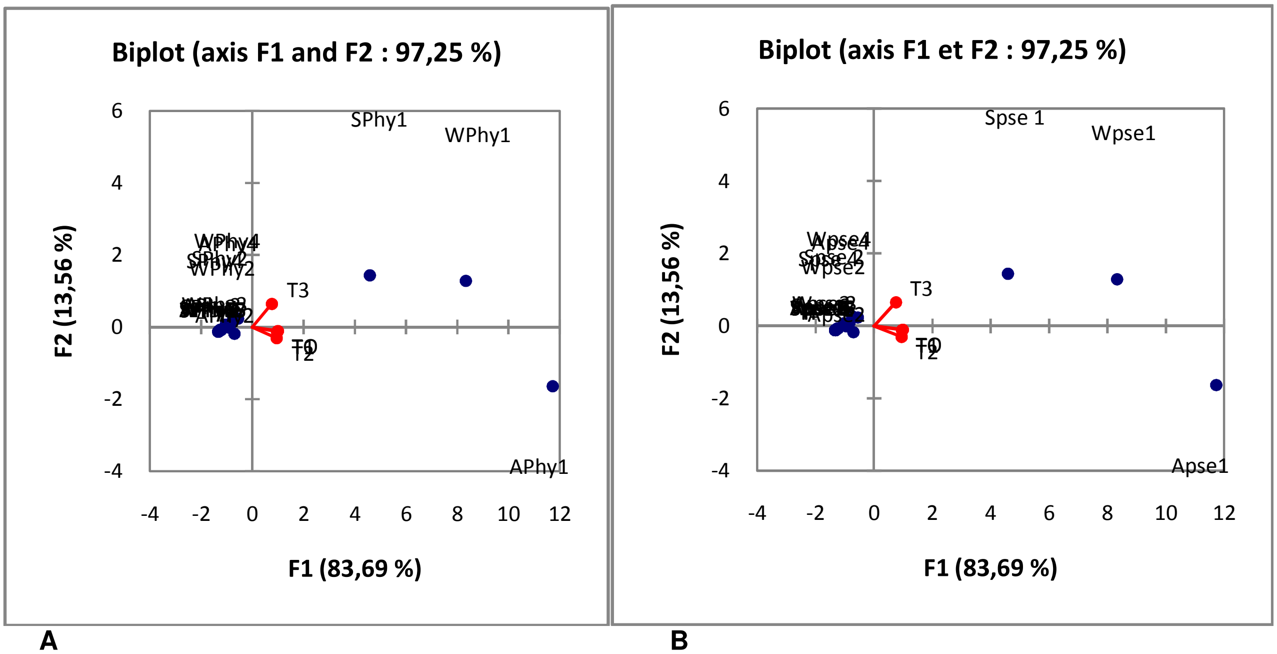

Figure 4. Analysis of relation phytomass and sequestration of carbon between for plants formations and wood logging in guinea savannas of Ngaoundéré, Adamaoua Region.

DISCUSSION

Periodic production of the phytomass of arborescent savanna in relation to the seasons and wood loggings in the guinea savanna of Ngaoundéré was very high.This result corroborates a similar study by Terakunpisut *et al.* (2007) who showed that the average biomass above the ground in Ton Mai Yak station (tropical rain forest) and KP 27 station (dry evergreen forest) were 275.46±96.15 $t.ha^{-1}.year^{-1}$and 96.28±33.44 $t.ha^{-1}.year^{-1}$ respectively in the Thong phaphum National Forest Thailand. The phytomass production of the ligneous depends on the period of plant production. The low production of phytomass in the dry season would be due to the depressive effects of wood loggings, bush fires and pastures on the vegetation. Tchobsala (1997; 2003) had shown that the dry season had a negative impact on the density of the ligneous. The total production of the phytomass of the ligneous also depends on the types of savannas. Shrubby savanna had the lowest production of phytomass when compared to those of the arborescent savanna and woody savanna. Similar results were obtained by Brown (1997) who respectively found 45 t. $ha^{-1}year^{-1}$, 43 t $ha^{-1}year^{-1}$and 32 t $ha^{-1}year^{-1}$in the Malian, Chadian and Senegalese shrubby savannas. Indeed shrubby savannas of the outer-urban zone of Ngaoundéré are situated in the zone of transition between the rain forest in the South and the dry savannas of the North Cameroon. These savannas are severely threatened by wood loggings and consequently they are placed in the same climatic and ecological conditions as the Malian, Chadian and Senegalese savannas. Results obtained from the arborescent savannah showed similar findings to those reported by Lamotte and *al.* (1983) who found 150 t $ha^{-1}year^{-1}$of phytomass in the arborescent guinea savannas of the tropics. Ibrahim *et al.* (2008) also found a similar result (145.12 t $ha^{-1}year^{-1}$) in the shrubby and arborescent savannas. In Ngaoundéré, the arborescent savannas are protected for the greater part by the regional services of forest protection and the rangers of Alladji Abbo. This protection of the vegetation allowed this one to affect one tree like stratum that is very different, giving a speed growth of forest as showed by Greg *et al.* (1998).

The production of herbaceous stratum in the various plant formations shows that the woody savannas are more important in the guinea savannas of the Adamaoua Region in Cameroon it justifies itself by the emergence of tall grass under the guinean climate. Our results confirm those of Doncfack (1998) in the zones of Gazad and Mitawa in the North Cameroon which found a strong production of herbaceous stratum during the year when the precipitation were very high. The strong production in our savannas is connected to the rainy season where animals graze little in woody savannas because of the presence of tall grasses and some streams. During this period shepherds prefer to graze their animals in shrubby or arborescent savannas. Indeed, the pasture and bush fires are very depressive factors for the reduction of the herbaceous phytomass. Similarly, Dembélé (1996) and Donfack (1998) showed that pasture tends to reduce the accumulated herbaceous phytomass, but differently according to their intensity, violence and period (premature and late bushfires).

The treatment T_0 presents a very sharp important biomass of dry weight with regard to the other treatments; it is because of the low pressure of the wood loggings that imposes a strong production of the herbaceous biomass. Doncfack (1998) stated this result by showing that the plot of land (T_0) against the fire and the pasture has a sensitive increase on the production of herbaceous phytomass between 1991 and 1994 in the zones of Gaza and Midawa. Indeed, we would expect that the treatment (T_3) altogether has a low production of herbaceous stratum with regard to the other treatments because the strong activities of wood loggings come along with a decrease of herbaceous stratum. But, we realized that the treatment (T_3) in the woody savanna presented a bigger production of herbaceous phytomass. In fact, in the woody savannas, the cleared or pierced created by wood loggings allow a good production of herbaceous stratum which is not any more suppressed by the big trees. Doncfack (1998) showed that the cuts of the wood influence the herbaceous carpet by the increase of the degree of cover which it provokes. Our results also confirm those of Doncfack (1993) who showed that in the Sudanese savannas, the production of the herbaceous biomass is 3 times higher in the outer of the ligneous covering than under the cover of the big trees. This production is between 5 - 6 tons of dry material by hectares in savannas outside the ligneous setting. Ntoupka (1999) showed that the wood loggings have an influence on the herbaceous carpet. The phytomass accumulated after 9 years is more important under the traditional rotational wood logging after three years than under the improved rotational wood logging after 6 years.

The production of carbon (t C) is proportional to the quantity of the phytomass produced in the various types of savannas. This shows that the woods and shrubs produce more carbon as compared to the herbaceous stratum, the cut stumps and the litter. In fact, phytomass is constituted of branches and leaves that contain chlorophyll pigments that permit to make photosynthesis, releasing CO_2 in the atmosphere. The different types of trees' cuttings practiced in the out skirts of Ngaoundéré are major factors of the degradation of the guinea savanna in the region. That degradation of the vegetation results to the drastic decrease of the phytomass and consequently of stocked carbon in the plants. Carbon released in the atmosphere depend on the density of trees' cutting in the shrubby arborescent and woody savannas. The quantity of carbon obtained in the guinea savanna of Ngaoundéré is more than that of dry Sudanese savannas and is approximately the same as those of guinea savanna. In Adamaoua region, the low production of carbon found in the areas highly cut showed that intensive trees' cutting reduces the production of carbon. Similar results have been found by Zapfack (2005) in the region of Yaoundé where areas suitable for cultivation produces less carbon. In fact, when a field is transformed into cultivation area or is highly cut for firewood, great quantity of carbon is produced. Houghton (1991) showed that deforestation results automatically in global land change with a reject of carbon in the atmosphere and increase in temperature.

There was a strong correlation between the production of phytomass and carbon sequestration in the three types of savanna in Ngaoundéré. This emerges from the fact that the quantity of phytomass synchronizes positively with the production of carbon. The weak correlation between the production of phytomass and the production of carbon implies the fact that when the quantity of held carbon increases the phytomass is important, but when it declines the quantity of phytomass also declines. The raw phytomass and the carbon are important in arborescent savannas with treatments T_0 and T_2. The loss of phytomass is very important in the plots with high cuts (T_3). By grouping together the eight parameters of phytomass production phytomass and carbon sequestration carbon in the savannas, we realize that the phytomass and the quantity of carbons stored in the various types of savannas respect the same classifications. What shows the resemblance is the correlation between both the phytomass and carbon sequestration. This is demonstrated as the following ranked ordered:

P1 ›P_2› P_4› P_3 ›P_7› P_8 ›P_5 ›P_6 in shrubs savannas; P1 ›P4› P2› P3 ›P7› P5 ›P8 ›P6 in arborescent savannas;

P1 ›P2› P4› P3 ›P7› P5 ›P8 ›P6 in woody savannas

The classification of the carbon sequestration according to the eight parameters and the three types of savannas appeared also in the same way as it is aforementioned.

CONCLUSION AND RECOMMENDATIONS

Savannas deforested for farmland and for fire wood have a very low production of phytomass. Shrubby and arborescent savannas are the most threatened causing. Weak phytomass production and stock of carbons which could be the cause of the advance of desert, heat and change of the climate and rain falling the Adamaoua Region of Cameroon. Positive correlations were found between ligneous and herbaceous phyomasses and between the total phytomass and carbon sequestration in the outer-urban savannas of Ngaoundéré. To increase the production of the savannas which is in decline and to facilitate the regeneration, environmental education to the local populations on the techniques of cuts, loggings of trees and methods of regulation of carbon sequestration must be made and supported by the divisional and regional delegations of Forest and Wildlife. The evaluation of phytomass and carbon under the effects of wood loggings has to take into account the heterogeneousness of savannas and the human activities (non- ligneous forest produce, agriculture, pastures) because the production of these parameters depend on the state of disturbance of these savannas. The techniques of rotations of the cultures and the wood loggings must be advised in all the Sudanian zone of Cameroon. The development of agro-forestry, governmental support to the afforestation of the cleared spaces and the development of alternative sources of energy to wood (solar furnaces, improved hearths) should be encouraged.

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