Original Research paper

Carbon stock as related to fallow age in the Sudano-guinea Savannahs of Ngaoundere, Adamawa, Cameroon.

Abstract:

Aims/ objectives: In order to assess the fallows contribution on the carbon cycle and soil organic matter restoration, a study of the carbon dynamic was undertaken in fallow systems of 1, 2, 5 and 20 years old in the Ngaoundere savannahs of Cameroon.

Methodology: Carbon stock was estimated in 100 m^2 plot for shrubs, of 1 m^2 plot for understorey, litter and earthworm casts, and 0.0625m^2 plot for fine roots and soil. The experimental design was randomised complete block with three replicates. The age of fallows was the mean treatment whereas the plots were the replicates.

Results: The mean results showed that the phytomass increased with fallow age, excepted that of shrubs. Soils and earthworm casts were the mean reservoir of carbon amount in the four fallows, with more than 55.61% and 26.24% of the total carbon stock respectively in the soil and earthworm casts. The carbon stock increased with fallow age, from 34.54 in the young fallows to 154.52 $tC.ha^{-1}$ in the old fallows. In the same way, vegetation and soil carbon increased with fallow age except that of shrub. The results showed that the carbon amount was influenced by floristic composition and spatial distribution of the vegetation, which related to follow age.

Results: These preliminary results will contribute to the understanding of the impact of fallow age on the global carbon cycle and awareness in the conservation of fallows for the environment protection.

Comment [u1]: There can only be one aim with several objectives

Comment [u2]: Check the tense

Comment [u3]: Follow or fallow

Comment [u4]: Did you mean results or conclusion?

Keys words: Phytomass, Carbon stock, Fallow age, Sudano-guinea savannahs, Ngaoundere, Cameroon.

Declaration of originality: Je declare the manuscript is the result of our research work.

Comment [u5]: Je or We?

1. INTRODUCTION

The degradation of natural resources through anthropogenic pressure such as bush fires, overgrazing and uncontrolled logging [1-2], due to population growth, is becoming increasingly important for agro-sylvo-pastoral development in the African savannahs [3-4]. This degradation leads to yield reduction, poverty and food insecurity due to an accelerated increase in the demand for arable land, which results in the fragmentation of savannas, the disappearance of biodiversity, the depletion of soils in organic matter and nutrients [5] and the modification of the biogeochemical cycle, in particular that of carbon [2] and the reduction of fallow age.

Land set aside is one of the most effective ways to restore degraded soils and ensure sustainable development in rural areas where farmers are mostly poor. Indeed, one of the most important roles of fallows is the biodiversity conservations, the maintenance or increase of soil fertility and carbon sequestration [6-8]. In particular, it is carbon that plays both a key role in soil fertility by constituting energy compounds necessary for biological activity, but also in the environment more specifically in climate change.

Over the last decade, the need to reduce the adverse effects of climate change has created a need for information on the vegetation and carbon stock dynamics over time and space in land-use systems. In order to define a global climate policy, reliable estimates of carbon stocks in forest ecosystems are needed [9]. In this context, agroforestry and the rehabilitation of fallows are now perceived as land-use options that can resolve some environmental threats in tropical countries where forest degradation is a major issue [9].

In the face of these economic, ecological and social issues, it becomes essential to provide more accurate estimates of forest carbon stocks and their dynamics in land use and land cover, and to understand the role of these systems and in particular their potential for mitigation and adaptation to global warming. A time averaged carbon stock of each land use should be evaluated and the resulting economic value deduced [10]. Hence the interest of the present study which will contribute to estimate the carbon stock in fallows of different ages.

Despite this important economic, ecological and social role, very little information on carbon stock in fallow systems is available in the Sudano-guinea savannahs of Adamawa, except those of Madjou [11], Nguilandi [12] and Saifoullah [13], who have as part of their Master's thesis in Science, estimated the carbon stock in simple fallows. This study therefore aims to evaluate the influence of fallow age on the carbon stock in the Ngaoundere savannahs in order to promote the renewed interest of farmers to leave their lands in fallows and the contribution of these to carbon sequestration.

2. MATERIALS AND METHODS.

Comment [u6]: Remove full stop

2.1 Study sites.

The study was conducted in the agricultural buffer zones of the sudano-guinea savannahs of Adamawa Cameroon, situated between the 6th and 8th degree of latitude North and between the 11th and 15th degree of longitude East. This region covers approximately 72,000 km^2, with an average altitude of about 1000 m and occupies practically the center of Cameroon. The climate is humid sudano-guinea type [14], with a unimodal rainfall distribution. Mean annual rainfall is about 1500 mm. The rainy season extends from July to September and dry season stretches from November to March. Mean annual temperature is 23°C and mean relative annual humidity is 65% [15]. While Ferralitic soils are the dominant types [16], with rich clay (40 à 60%), low organic matter (less than 3%), low soil exchange capacity from 15 to 20 meq/100g and the pH 4.7 to 5.6 [17]. Vegetation of Adamawa is a humid savannah type, consisting of shruby and woody savannahs. These savannahs originally populated with *Daniellia oliveri* and *Lophira lanceolata* [18]. There were also hydromorphic meadows that were sometimes inundated and contained *Hypparhenia rufa*, forest galleries with *Syzygium guineense* var. *guineense* and *Berlinia grandifolia*, fallow lands and savannahs, occasionally used as grazing lands which were composed of *Acacia hockii*, *Afzelia africana* [18]. Now, this vegetation is much reduced under the influence of zoo-anthropic factors such as wild fires and rearing [19-20]. Agriculture is still traditional. Livestock remains the main economic activity practiced by the more than 20% of the rural population. Other activities like hunting, fishing and crafts are practiced at artisan level in the region. The most relevant problems in the region include the permanent decline soil fertility, damages by Striga on cereals and termites on crops.

Comment [u7]: 8th and not 8th

Comment [u8]: Check for he correct spelling

2.2 History of fallows

To estimate the carbon pool in the fallow systems of the Ngaoundere wet savannahs, four predominant fallow types in the region were selected near the University of Ngaoundere. It's a one-year fallow (F01) dominated by herbaceous stratum characterized grasses**,** two-year-old (F02) grass-dominated, five-year-old (F05) dominated by grasses and high herbaceous, and finally twenty years (F20) dominated by young shrub stands. These fallows are located on sites of the same topography, similar color and soil texture, but with different physiognomy and structure of vegetation, and plant species composition. These sites are protected against wild fires, loggings. The soils of these sites are of the ferrallitic type with clay texture. The

Comment [u9]: Report in past tense

other site characteristics, their geographical location and their dominant vegetal formation were given in **Table 1**.

Before 1997, the one-year fallow was a savannah that, from that date, was cultivated for 9 years. The first crops were maize-associated beans, which lasted 4 years, followed successively by sweet potatoes grown for 2 years, irish potatoes for 1 year and finally maize for 2 years. The second 2-year-old fallow was grown for 11 years. Previous crops were yams and sweet potatoes, which lasted 3 years, solanaceae 5 years, maize associated with sweet potatoes 2 years, and Fabaceae (1 year). For 5-year fallow, the previous crops were cassava and rotary crops of solanaceae (peppers and aubergines). For 20-year-old fallow, the previous crops were maize, sweet potato, and then peppers and aubergines. Because of the decrease in productivity over the last two crops, the farmers have put these plots into fallows.

Comment [u10]: Use sentence case

2.3 Phytomass estimation

Phytomass was estimated in three plots of 100 m^2 (10 m x 10 m) in each type of fallows. To minimize spatial heterogeneity, the plots were not far apart. In these plots, the biomass of shrubs, herbaceous and root, the dry mass of earthworm casts and soil bulk density were determined according to the methods used by the following authors [21-23]. During the biomass estimation, floristic composition and specific plant names were recorded. The experimental design was a completely randomized block with three repetitions. The fallow types were the treatments and the plots or subplots were the repetitions.

2.4 Above-ground phytomass

Shrub biomass was estimated in 100 m^2 plots (10m x 10m). The shrubs have been inventoried. Their name, basal diameter (15 cm) and height were recorded. These shrubs were then cut to the ground with a machete and separated by fraction (leaves and wood). The total fresh masses of each fraction were determined using a weigh (*Sartorius ISO 9001*). A sample of each fraction was taken and its fresh mass determined by weighing. It will be used to estimate the water content of the shrub fractions and to carry out further analyzes in the laboratory. Shrub litter was also collected in each sub-plot and sorted to remove numerous remains. Their fresh mass was determined as before and a sample was taken.

Herbaceous biomass and litter mass were estimated in five 1m^2 (1m x 1m) subplots, delineated at each top and at the center of the 100m^2 plot. All species that are outside the sub-plot but are rooted in it were sampled. On the other hand, species rooted outside are excluded from sampling. All the herbaceous plants sampled were cut to the ground and separated into "living" and "dead" components. The total mass of each component was determined by weighing and a sample was taken as before.

2.5. Below ground phytomass and soil mass

Root biomass was estimated in 25 cm square plots at the center of each sub - plot. Soil blocks of 6250 cm^3 (25 cm x 25 cm x 10 cm) and 9375 cm^3 (25 cm x 25 cm x 15 cm) were extracted at two depth levels: 0-10 and 10-25 cm. These previously weighed blocks were sieved using a 1-mm mesh sieve, then the roots were manually sorted and separated into two classes according to their diameters [24]: fine roots (<2 mm) and small roots (2 -5 mm). These two root groups were then weighed. Before sieving, a sample of soil was taken and weighed to calculate its water content and bulk density.

Earthworm casts were collected in the five subplots of 1 m^2 (1 m x 1 m). Their total fresh mass was determined as before and samples were taken. Soil blocks used for the study of roots were used to estimate the bulk density of soils. The total fresh mass of the blocks and those of their samples were determined by weighing.

2.6 Determination of dry mass

All samples (leaves, wood, litter, grass, soil, earthworm casts) and root samples were brought back to the laboratory in craft paper bags to be dried at 60°C in an oven for 48 hours, that is to say until reaching a constant dry mass.

The water contents of all samples were calculated using the following formula:

$$WC\ (\%) = ((FM - DM)/\ DM) \times 100$$

Where WC is the water content of the samples (in % of dry mass), FM is the fresh mass and DM is the dry mass of the samples.

From the water contents of the samples (vegetation, earthworm casts and soil), the total dry masses were calculated as follows:

$$TDM_v = 100 \times TFM / (100 + WC)$$

Where TDM_v is the total dry mass (g) of vegetation and TFM is the total fresh mass (g).

From the TDM_s of soil samples, the bulk density of soil (D) was calculated as follows:

$$D = TDM_s / (L^2 \times h)$$

Where L is the side of the soil block (25 cm) and h is the height of the block or the depth of the hole (10 or 15 cm).

The total dry mass of vegetation called phytomass was expressed in tone per hectare ($t.ha^{-1}$), as well as for that of earthworm casts and the bulk density of the soil ($kg.m^{-3}$).

2.7 Chemical analysis

All samples of a plant fraction (leaves and wood) and a vegetation component (grass and litter) or a category of roots and soil samples of a plot were grouped into one. This gave 60 samples which were distributed as follows: six samples (2 sites x 3 repetitions) of leaves, litter, grass, wood and earthworm casts and 24 root samples (2 sites x 2 diameters x 2 depths x 3 repetitions) and 12 soil samples (2 sites x 2 depths x 3 repetitions). These samples, after reduction to powder using a *Micro Hammer Mill Culatti* equipped with a 1 mm filter, were analyzed in the laboratory of the Department of Food Sciences and Nutrition (SAN) of the National Higher School of Agro-Industrial (ENSAI) of the University of Ngaoundere. The carbon content was determined by the modified Walkley-Black method [25].

2.8 Estimation of carbon stock

From the total dry mass (TDM) of vegetation components, earthworm casts and soil bulk density (D), and their carbon contents, the carbon quantities were calculated as follows:

$$QC_v = (TDM \times C_i)/100 \text{ for vegetation and earthworm casts,}$$

$$QC_s = (D \times C_i \times h)/100 \text{ for soil}$$

Where QC_v is the carbon amount of vegetation and earthworm casts expressed in tC.ha^{-1}, QCs is the carbon amount of soil, h is the soil depth and C_i is the carbon content (%) of soil.

2.9 Statistical analysis.

ANOVA were used to compare, among 4 fallows, the studied parameters (mass and carbon of shrubs, herbaceous, roots, litter, soils and earthworm casts). These analyzes were followed by a comparison of means by Scheffe's test at 5%. Student's tests were also used to compare soil depths and fine root biomass. These analyzes were performed using the Stagraphics plus 5.0 software.

Comment [u11]: Were or was?

Comment [u12]: Reconstruct and indicate if it is Student t-test

3. RESULTS

3.1 Floristic composition of fallows.

Fallows differed in their plant species composition **(Table 2)**. They are constituted by annual or perennial herbaceous plants, in particular grasses, young shrubs and rejections. Indeed, in the one-year fallow, there was an abundance of annual grasses as *Pennisetum pedicellatum*, *P. polystachion*, *Eragrotis tremula* and *Hypparrhenia involucrata*. Shrub **rejects** such as *Piliostigma thonningii* and *Terminalia glaucescens* were beginning to develop. In the two-year fallow, persisted Pennisetum. Other perennial grasses as *Eragrotis atrovirens* and

Andropogon gayanus, emerged to replace *Eragrotis tremula* and *Hypparrhenia involucrata*, which are annuals. Perennial herbaceous weeds such as *Sida rhombifolia* and *Waltheria indica* and shrubs as *Gardenia aqualla* were also developed. In the five-year fallow, the vegetation was mainly represented by perennial herbaceous (Fabaceae, Poaceae, etc.) where the genus, Crotallaria, Indigofera, stylosanthes and waltheria, predominated numerically. In the 20-year fallow, two strata were present, the low strata being dominated by perennial herbs like *Andropogon gayanus* and the high strata dominated by a very important young woody population such as *Hymenocardia acida*, *Lophira lanceolata*, *Piliostigma thonningii*, *Terminalia glaucescens* and *Syzygium guineense* var. *macrocarpum.*

Comment [u13]: remove

3.2 Above-ground phytomass

The total phytomass obtained varied significantly ($P < 0.05$) among fallows and increased with fallow age **(Fig. 1)**. This phytomass ranged from 10.53 t.ha^{-1} in one year old fallow to 41.97 t.ha^{-1} in the 20 year old fallow. The increase in phytomass was low between one and five year-old fallows, while that of the twenty-year-old fallow represented two to four times that of the five-year old and one-year old fallows, respectively. In the same way, these fallows differed significantly from one another by herbaceous phytomass, litter and roots **(Table 3)**. In contrast, shrub phytomass did not differ significantly ($P > 0.05$) among fallows. The contribution of vegetation components (shrubs, herbaceous, litter and roots) to total phytomass was variable. For all fallows, herbaceous accounted for most of the phytomass, as their contribution to total phytomass was highest, with rates of 74, 75, 75 and 82% respectively in 1, 2, 5 and 20 year old fallows; those of litters were the lowest, with rates of 0.9, 1.6, 1.4 and 0.9% respectively in the same fallows. Contributions from other components of vegetation to total phytomass were intermediate.

3.3 Below-ground phytomass

The dynamics of root phytomass in fallows varied with depth **(Table 4)**. For all fallows, the root phytomass decreased significantly from the soil top (0-10 cm) to the depth (10-25 cm). In the soil top (0-10 cm), the root phytomass was at least three times higher than that located in the soil depth (10-25 cm) for fallow of 1, 2 and 5 years. On the other hand, it was only about two times in the fallow of 20 years. This phytomass of the fine roots did not vary with the fallow age for the soil top **(Table 4)**. The production of these roots varied significantly among fallows of different ages for soil depth (10-25 cm). The phytomass value of 20-year-old fallow roots (2.08 t.ha^{-1}) was 2.8 and 3.7 times higher than other fallow with a phytomass ranged 0.56 and 0.73 t.ha^{-1} in soil depth (10-25 cm).

3.4 Carbon stock in vegetation and soil

Total carbon stock in fallows increased with age, from 34.52 tC.ha^{-1} in one-year old fallow to 154.85 tC.ha^{-1} in 20-year old fallow **(Fig. 2)**. This increase in carbon over 20 years was 4 times that stored in one year fallow. This trend of carbon stock increase with the age of fallows was also observed in the plant compartment as well as in the soil-earthworm casts compartment. The latter compartment was the most important carbon storage reservoir **(Fig. 2)**, since more than 80% of carbon was stored in the soil *vs* less than 20% in the vegetation. Similarly, the amount of carbon in vegetation components and soil differed significantly ($P < 0.001$) among fallows, with the exception of shrubs **(Table 5)**. With regard to vegetation components, most of the carbon was stored in herbaceous, with high rates of 67% (3.62 tC.ha^{-1}), 59% (4.37 tC.ha^{-1}) , 47% (7.96 tC.ha^{-1}) and 42% (11.49 tC.ha^{-1}) respectively in fallows of 1, 2, 5 and 20 years old **(Table 5)**. The amount of carbon stored in the shrubs was the lowest because it was between 3 and 5% of the total stock, *i.e.* between 0.17 and 1.02 tC.ha^{-1} respectively in the fallows of one and 20 years, while this accumulation was intermediate in litter with rates of 13, 23, 38 and 47% respectively in fallows of 1, 2, 5 and 20 years. In the 5-year and 20-year-old fallows, the soil and the earthworm casts constituted the important reservoir of carbon with more than 40% of total carbon stock, *i.e.* more than 50 and 63 tC.ha^{-1} respectively in fallow of 5 and 20 years old. While in the one-year and two-year fallows, soil was the main carbon reservoir, with respectively 27.02 and 31.10 tC.ha^{-1}, or 70% contribution rate per year to the total amount of carbon. With respect to roots, the carbon amount accumulated in roots varied significantly ($P < 0.05$) among fallows according to soil depth and fallow type **(Table 6)**. This carbon amount was significantly higher in the soil top (0-10cm) than in the soil depth (10-25cm) for all fallows. It increased significantly with age of fallows in both depths **(Table 6)**. It ranged from 0.72 and 0.19 tC.ha^{-1} in one-year fallow to 1.69 and 0.66 tC.ha^{-1} in 20-year old fallow respectively for depths of 0-10 and 10-25 cm.

In general, the importance of carbon reservoir varied with vegetation components and soil, and according to fallow ages **(Table 5)**. In order of decreasing importance was: soil > herbaceous > earthworm casts > fine roots > litter > shrubs in one-year fallow, soil > earthworm casts > herbaceous > litter > fine roots > shrubs in fallows of 2 and 5 years and finally soil > earthworm casts > litter > herbaceous > fine roots > shrubs in the fallow of 20 years. Soil was the most important carbon reservoir with a contribution of more than 40% compared to the total stock of carbon stored regardless of fallows.

4. DISCUSSION

4.1 Floristic composition of fallows

The floristic composition of fallows finding in our study can be explained by the plant succession that determined the density and spatial arrangement of woody plants during the dynamics of fallows. Indeed, César and Coulibaly [26] reported in their work on the Korhogo savannah in Ivory Coast, characterized by six months of rainy season, that the pattern of dynamics of natural vegetation of fallow is partly according to the age of the latter: in recent fallow (1-3 years), weeds and annual grasses dominated; in a young fallow (3-5 years), perennial grasses settled; in a fallow of 5-15 years, the genus Andropogon dominated the flora and in a fallow of 15-25 years, Andropogon dominated and then the structure of the savannah reconstituted by the installation of a young woody stand. In their part, Duvineau and Fournier [27] showed that *Andropogon gayanus*, a perennial grass, usually dominated the herbaceous vegetation of fallow in the Sudanian zone after ten years. Other authors have reported that the physiognomy of fallow vegetation varies with the age of fallow. Indeed, in Bondoukuy, Burkina Faso, four types of fallow vegetation (or stage) physiognomy could be distinguished. Annual weeds such as annual grasses with *Eragrotis tremula* and *Digitaria horizontalis*, dominated the first stage (1st year). During the second stage, other annual grasses were required (*Eragrotis turgida*, *Brachiaria ramosa* ..) while transitional perennial grasses such as *Andropogon gayanus* appeared. The latter dominated ten years (third stage) before giving way to perennial grasses of savannah (fourth stage) such as *Andropogon ascinodis*, *Schizachyrium sanguineum* [27-29]. It was only at the end of succession that the diversity of woody plants was completely restored, but many plant species were already meeting at five years of fallow [30]. This establishment of fallow vegetation can be explained by their germinative capacity [31]. In fact, apart from the vegetatively propagated perennial species such as *Imperata cylindrica* or *Launea cornuta*, the diffusion of which is favored by soil work, in most cases savannah perennial grasses, and in particular *Andropogon gayanus*, are often eliminated during clearing and weeding. In summer fallow (first stage), their population is struggling to rebuild because of the lack of seeds and the fact that their seeds have a low germinative capacity [32-33], On the other hand, many annual species are well adapted to cultural conditions such as the large-scale production of seeds with high germinative capacity [34], late or staggered germination and/or the completion of several vegetative cycles during the

Comment [u14]: change to full stop

rainy season. They develop their populations during crop cycles and constitute the weed populations of the fields that are responsible for the vegetation of the young fallows [35-36].

4.2 Fallow phytomass

The total phytomass of fallows of the Sudano-guinea savannah of Ngaoundere obtained just at the end of the rainy season ranged from 10.53 $t.ha^{-1}$ to 41.97 $t.ha^{-1}$. Comparing these values with data from the African savannahs, the phytomass found in our study were higher than those reported in African savannahs. Indeed, in Sudanian fallows studied at Kolda, above-ground biomass ranges from 18 and 41 $t.ha^{-1}$ [37]. Other studies have reported lower values [35, 38-40]. As in our study, litter mass was low in fallow and ranged from 1.5 to 2.7 $t.ha^{-1}$ in the least anthropized and wettest site in Senegal [37]. This low mass of litter is explained according to Serpantié and Ouattara [38] by the intense activity of decomposers at any season and the sampling period.

On the other hand, our results confirmed those of the literature concerning the pattern of an increase of the phytomass with the age of fallows. Indeed, in the Sudano-guinea zone, César and Zoumana [35] evaluated, in 1989, maximum phytomasses which vary respectively in a ratio of 1 to 3.5 on a degraded fallow (1 $t.ha^{-1}$), a fallow in restoration course (2 $t.ha^{-1}$), old undegraded fallow (3.50 $t.ha^{-1}$) and reconstituted savannah (4.90 $t.ha^{-1}$). Similarly, in Sudanian fallows studied at Kolda, above-ground biomass doubled between young and old fallows, from 18 to 41 $t.ha^{-1}$. In the Sudano-sahelian zone, Banoin and Achard [41] recorded maximum phytomass values of 1.25 $t.ha^{-1}$ in *Zornia glochidiata* fallows, aged between six and fifteen years, whereas they reached 2.50 $t.ha^{-1}$ in those to *Loudetia togoensis* and *Zornia glochidiata*, older, located on the same soil. However, this increase in phytomass with the length of fallow periods faded or even decreased from a certain age of fallows, which was variable according to phytodiversity and ecological zones [37]. Indeed, Da Costa [42], working on fallow systems in Mozambique, has shown that biomass increases from young fallows (0-5 years old) to old fallows (11-20 years old). On the other hand, this biomass decreased beyond this age. The biomass of old fallows (11-20 years) was 4 times higher than that of young fallows (0-5 years). On the other hand, for very old fallows (33 years old), this biomass was lower than that of old fallows (11-20 years). In Kolda, the high biomass in the Young fallows increased from 5.8 $t.ha^{-1}$ to 1.8 $t.ha^{-1}$ in older fallows. Under these conditions, the total above-ground biomass available for burning tends to decrease with the age of fallow from the five years. It should be noted, however, that this paradoxical result holds for a site where short-term cultivation maintains a good regeneration potential for woody plants and where wood was heavily used [37].

The contribution of herbaceous was very high and sometimes reached a rate of 82% compared to the total phytomass. These results were consistent with those of Achard et al. [40] who showed that in the savannah of Ticko in Senegal, the herbs of a fallow represent 90% of the total phytomass. The high contribution of the herbaceous and the low litter mass on the soil can be explained by the sampling period which is located at the beginning of the dry season.

For all fallows, root phytomass decreased significantly with soil depth. In the soil top (0-10 cm), the root biomass was at least three times higher than that located at the soil depth for fallows of 1, 2 and 5 years. On the other hand, it was only about two times in the fallow of 20 years. This large production of fine roots on the soil top was due to the accumulation of organic matter and the intense biological activity in this part of the soil. This result confirmed those of Kanmegne et al. [43] in the forest zone and Madjou [11] in the Sudano-guinea savannahs of Cameroon. On the other hand, the production of fine roots increases significantly with fallow age only at soil depth (10-25 cm). Similar results have been reported by Serpantié and Ouattara [37] who have shown that fine root biomass in the annual herbaceous and shrubby fallows of Kolda, varies from 1.6 t.ha^{-1} under short fallow to 3.2 t.ha^{-1} under old fallow. On the other hand, Lamotte and Bourlière [44] showed that root biomass ranged from 1.6 t.ha^{-1} in young fallows to 17 t.ha^{-1} in older fallow in the soil top. Similarly, Manlay and Masse [45], have shown that root biomass is of 4 t.ha^{-1} in 4-year fallow and 20 t.ha^{-1} in 20-year fallow. These results took into account fine and small roots.

4.3 Carbon stock

Several studies have shown that post-cropping fallows sequester carbon and can offer climate change mitigation opportunities in synergy with adaptation [46, 8, 47]. Our work showed that carbon stocks along the chronosequence increased with fallow age, from 34.52 tC.ha^{-1} in one-year fallow to 154.85 tC.ha^{-1} in 20-year fallow. This increase in carbon over 20 years was 4 times that stored in one year fallow. These patterns were consistent with observations by César and Coulibaly [26], Anobla and N'Dja [47], Manlay [48], Palm et al. [49], Simiane [50] and Gond et al. [51]. Indeed, in Saré Yorobana, in southwestern Senegal, Kaïré [52] found in the fallows of 5, 10, 15 and 20 years, an increase in the carbon stored in the biomass of 5, 11, 15 and 18 tC.ha^{-1}, respectively. The results obtained by Mass [53] in the same site as Kaïré [52] showed that fallows less than 10 years accumulated on average a carbon stock (soil + plant) of 17.5 tC.ha^{-1}, whereas Fallows older than 10 years averaged 22.5 tC.ha^{-1}. Gond et al.

[51] showed that in the Plateau of Batéké in DRC, the carbon stock in old fallow (17 tC.ha^{-1}) was more than 5 times higher than that in young fallows (3 tC.ha^{-1}). For their part, Palm et al. [49] reported the same results for Kenyan savannahs as the previous authors. Old fallows over the age of 25 have accumulated between 64 and 131 tC.ha^{-1} more than young fallows of less than 5 years old (5-20 tC.ha^{-1}). Anobla and N'Dja [47] found in the forest fallows of the Bamo forest in Ivory Coast, old fallows store more carbon than young fallows and this carbon change in fallow biomass of 4-8, 9-13, 14-20 and 15-24 years is 80.25, 91.75, 211.75 and 256.50 tC.ha^{-1}. In the forest fallows of Talamanca in Costa Rica, Simiane [50] found that the amounts of carbon stored in fallows were strongly and positively correlated with the age of these fallows. In the Mozambique Savannahs, Da Costa [42], reported a positive and significant correlation ($R^2 = 0.54$ and $P < 0.001$) between carbon stock and fallow age. Similarly, in the savannahs of southern Senegal, Manlay [48], observed the same patterns for total carbon stock and its above-ground and below-ground carbon stock in young and old fallows, except for herbaceous carbon. For the latter, its observations were contrary to ours, because the carbon stock of the old fallows were lower (0.54 tCha^{-1}) than those of the young fallows (2.14 tCha^{-1}). Overall, whether forest or savannah, old fallows sequestered more carbon than young fallows with some exceptions reported in the literature when looking at the details of total carbon components [48] or when it comes to very old fallows [42].

In contrast, the carbon stock calculated in this study was higher than most of the literature results [49, 48, 54, 50, 47]. Because we found 34.52 tC.ha^{-1} in young fallows of 1 to 2 years and 154.85 tC.ha^{-1} in old fallow of 20 years against 3 to 20 tC.ha^{-1} and 17 to 131 tC.ha^{-1} in the work of previous authors for young and old fallows respectively. On the other hand, for young fallows, Nolte et al. [54] found higher values (108 tC.ha^{-1}) than ours. For the old fallows, Anobla and N'Dja [47] have a value of 256.50 tC.ha^{-1}, much higher than ours. These differences were attributed not only to the plant species composition of fallow, in contrast to the methodological difference, especially the definition of young and old fallow. In fact, in our study, the age of young fallows is between 1 and 2 years whereas it is 4 to 8 years in the studies of Anobla and N'Dja [47], 5 years in those of Kaïré [52], Da Costa [42] and Palm et al. [49], less than 10 years in those of Mass [53]. Similarly, the age of old fallows is 20 years in our work and those of Kaïré [52], versus 10 years in the work of Mass [53] and 25 years in those of Palm et al. [49].

In general, the importance of carbon stock varied with the vegetation components and soil. These results show that it is the soil that represents the largest carbon reservoir with a contribution of more than 40% compared to the total amount of carbon stock. These results confirmed those of Madjou [11] who showed that the soil represented the most important carbon reservoir, with 90% of carbon stored. Similar results have been reported by San José et al [55]. According to them, the soils of the Australian savannahs abounded 40% of total stock of carbon. Other results have shown that even if above-ground biomass is destroyed, between 50 and 60% of the total carbon in the system is on the soil surface [56].

5. CONCLUSION

This study made it possible to estimate the carbon stocks in the different age of fallows of the Sudano-guinea savannahs of Ngaoundéré, Adamawa Cameroon. The main results show that these fallows stock on average a large amount of carbon, *i.e.* 14.82 tC.ha^{-1}, of which 8.42% (7.48 tC.ha^{-1}) was accumulated in aboveground biomass, 83.89% in soil (79.60 tC.ha^{-1}), 1.61% in belowground biomass (1.43 tC.ha^{-1}) and 6.08% in litter (5.41 tC.ha^{-1}). The carbon stock in the plant and soil compartments increased with the age of fallow, from 34.52 to 154.85 tC.ha^{-1} respectively for young and old fallows. Similarly, the carbon stock in vegetation components increased significantly with the age of fallows, except these of shrubs, *i.e.* 3.62 and 0.70 tC.ha^{-1} for young fallows and 11.49 and 12.80 tC.ha^{-1} for old fallow respectively for herbaceous and litter. The amounts of carbon accumulated in the fine roots decrease with depth, from 3.07 to 0.98 tC.ha^{-1} respectively for 0-10 and 10-25 cm depth. The soil compartment (including the earthworm casts) was the main reservoir of carbon, since more than 80% of total amounts of carbon were stocked in this compartment. These results confirmed the enormous potential of fallows in carbon storage. They can play a very important socio-economic and environmental role at the global, national and local levels when they are well conserved. For this reason, agroforestry development policies should encourage the conservation of fallows, including improved fallows.

REFERENCES

1. Ntoupka M. Production des Bois utiles sous perturbations anthropiques (pâturages et feux) dans la région soudano-sahélienne du Nord Cameroun. Actes du colloque Laforesterie de zone sèche Ouagadougou de novembre. nineteen ninety eight; 12 p.
2. Tchobsala, Ibrahima A, Dongock Nguemo D, Nyasiri J. The Impact of Anthropisation on the Floristic Composition, The Structure and Ecological Characterization of the Ngaoundéré Cliff, Cameroon. Global Journal of Science Frontier Research C. 2016; 16(3): 14-31.

3. Pontanier R, M'Hiri A, Akrimi N, Aronson J, Le Floc'h E. L'homme peut-il refaire ce qu'il a défait? Paris, John Libbey Eurotext. 1995; 455p.

4. Tchobsala, Mbolo M. Characterization and Impact of wood logging on plant formations in Ngaoundéré district, Adamawa region, Cameroon Journal of Ecology and the Natural Environment 2013; 5(10): 265-277.

5. Sounon B, Sinsin B, Goura S. Effet de la dynamique d'occupation du sol on the structure and the diversified floristique for the clayes and sages of Benin. Tropicultura 2007; 25(4): 221-227.

6. Smith WN, Wall G, Des Jardins R, Grant B. Carbone organique du sol. In: Smith WN, Wall R (Ed) La qualité du sol. Canada, Province. 1995; 85-92.

7. Kassi NJ Successions second-to-posters for post-culturals (Côte d'Ivoire): nature, structure and organizational fonctionnelle de la végétation. Thèse de Doctorat, Université de Picardie Jules Verne d'Amiens (France).2006; 212p.

8. Tayo GYK Dynamique de la biodiversité ligneuse and stock of carbone dos santèmes agroforestiers a base cactoyer center in Cameroun: cas of Ngomedzap (Cameroun). Mémoire de Master, Faculté Agronomique et des Sciuelo Université de Dschang (Cameroun). 2014; 91 p.

9. Torquebiau E, Mary F, Sibelet N. Les associations agroforestières and leurs multiples enjeux. Bois et Forêts des Tropiques 2002; 271: 23-36.

10. Minang PA, Jungcurt S, Meadu V, Murphy D. Negociations of the REDD: l'avancée vers Copenhague. International Institute for Sustainable Development (IISD). 2009; 31p.

11. Madjou TS. Quantification du carbone dans les jachères des Savanes de Ngaoundéré, Cameroun Mémoire Présenté and Soutenu on the Request for Diploma in Mathematics and Biology and Physiology (Option: Biologie Végétale). 2005; 31p.

12. Nguilandi Saolo P. Dynamique du Carbone et D'azote dell quelques de l'équire de Nágoundére, Cameroun. Mémoire de Maîtrise, Faculté des Sciences, Université de Ngaoundéré. 2007; 37p.

13. Saifoullah D. Land use systems and carbon sequestration in the savannah highlands of Ngaoundere (Adamawa Cameroon). Mémoire de Master II, Faculté des Sciences, Université de Ngaoundéré. 2014; 35p.

14. Suchel JB. La répartition des pluies et régimes pluviométriques au Cameroun, Center de Recherches Africaines, Université fédérale du Cameroun 1971; 29p.

15. Carrière M. Les communautés végétales sahéliennes en Mauritanie (Région de Kaédi), analyzes of the reconstitution annual du couvert herbacé. Thèse de Doctorat, Université de Paris Sud Orsay, IE.M. V.T. Maisons-Alfort, Cenerv., Nouakchott. 1989.

16. Boutrais J. Les conditions naturelles de l'élevage on the plateau de l'Adamaoua (Cameroun) ", Cahiers ORSTOM, Série Sci. Hum 1974; XV (2): 145-198.

17. Brabant P, Humbel FX. Notice explicative de la carte pédologique de Poli, No. 51, Carte au 1 / 50000e, Yaoundé. 1974.

18. Letouzey R. Etude Phytogéographie du Cameroun Paris P. Le Chevalier (Encyclopédie biologique-LXIX). 1968; 511p.

19. Yonkeu S. Végétation des Pâturages de l'Adamaoua (Cameroun): écologie and potential pastorales Thèse de Doctorat, Université de Rennes, France. 1993; 207p.

20. Mapongmetsem PM, Nkongmeneck BA, Rongoumi G, Dongock D, Dongmo B. Impact of Systèmes utilization of terraces on the protection of Vitellaria paradoxa Gaertn (Sapotaceae) dans la région des savanes soudano-guinéennes. International Journal of Environmental Studies 2011; 68(6): 51-72.

21. Anderson JM, Ingram JSI. Tropical soil biology and fertility: a hand book of methods C.A.B. International, UK; 1993.

22. Kotto-Same J, Woomer PL, Moukam A, Zapfack L. Carbon dynamics in slash-and-burn agriculture, and land-use options of the humid forest zone in Cameroon. Agriculture, Ecosystems and Environment 1997; 65:245-256.

23. Woomer P, Palm CA. An approach to estimating system is called a carbon stock in tropical forest. Commonwealth Forestry Review nineteen ninety eight; 77(3):181-190.

24. Vogt KA, Persson H. Measuring growth and development of roots. In: Lassoie JP, Hinckley TM (eds). Techniques and approaches in forest tree ecophysiology. Boca 1991; 477-501p.

25. Walkley A, Black CA. Center's expertise en analysis environnementale du québec et ministere de l'agricultur, des pêcheries et de alimentation du Québec, deforestation de la materie de carbone organiser dans les sols agricoles: methoth Walkley-Black modifiée, MA. 1010 - WB 1.0, Ministère de l'Environnement du Quebec. 2003; 10 p.

26 César J, Coulibaly C. Conspiracy de l'accroissement démographique on the qualité de la jacére dans le nord de la Cote d'Ivoire. In: Floret C, Serpantie G. (eds). La jachère en Afrique de l'Ouest. Collection colloques et séminaires, ORSTOM, Paris, 1993; 415-434.

27. Devineau JL, Fournier A. Synthese provisoire resulted in acquiring a perfect biology of Bobo-Dioulasso, Bobo-Dioulasso, Orstom. 1997; 77p.

28. Hien M. The reconstitution postcultura de la vegetation en Savane soudanienne dans la region de Bondoukuy (Burkina Fasso). Les Jacheres de mains de six ans: flore, persistance of adventures, and other uses of the world, the DEA, the sciences biologiques, the biology and ecology of the choice, the Faculty of Sciences and Techniques, the Ouagadougou University, the Botanical and Biological Vegetation of Labpratoire -Orstom 1996; 95p.

29. Fournier A, Nignan S. Quand's Annuelles blocant post-culturale Experiments on Andropogon Gayanus Ecologie. 1997; 28(1): 13-21.

30. Fournier A, Floret Ch, Gnahoua GM. Végétation des jachères et succession post-culturale en Afrique tropicale. In: Floret Ch, Pontanier R (eds). La jachère en Afrique tropicale: Rôle, aménagement, alternatives, Actes du séminaire international, Dakar, 13-16 avril 1999. 2000; 123-168.

31. Achard F, Hiernaux P, Banoin M. Les Jachères Fourragères naturelles and amélioras in Afrique de l'Ouest. In: La jachère en Afrique tropicale Floret Ch., Pontanier R. (eds), John Libbey Eurotext, Paris. 2001; 201-239.

32. Serpantié G, Madibaye D. Recherches participhers on the la cultures of Andropogon Gayanus Kunth var. tridentatus hack. En zone soudanienne II. Essais participates the installation of peuplements (Bondoukuy et Bereba, Burkina Faso). In: Godet et al (eds). Ce qu'il a déjà? Paris, John Libbey Eurotex.1998; 455p.

33. Dieng A, Buldgen A, Compere R. La culture, Fourth Arthropirer andropop, andropogon Gayanus Kunth Var bisquamulatus en zone soudano-sahelienne senegalaise 3. Influence the system's exploitation on production of the fourrage, Bull. Rech. Agron Gembloux. 1991; XXVI (3): 337-349.

34. Le Bourgeois T, Merlier H. Adventrop, the advent of the Afrique soudano-sahelienne, Montpellier, CIRAD CA. 1995; 637p.

35. César J, Zoumana C. Conspiracy de l'accroissement démographique on the qualité de la jachère dans le Nord de Côte d'Ivoire. In: Floret C, Serpantié G (eds.). La Jachère en Afrique de l'Ouest. Atelier International, Montpellier, France, 2-5 / 12/1991. ORSTOM 1993; 415-434.

36. Chikoye D, Ekeleme F, Akobundu IO. Weed composition and population dynamics in intensified smallholder farms in West Africa, Proceedings of the 1997, Brighton Crop Protection Conference - weeds, IITA, Ibadan. 1997; 161-166.

37. Serpantier G, Ouattara B. Fertilize et jachère en Afrique de l'Ouest. In. La jachère en Afrique tropicale De la jachère naturelle à la jachère améliorée Le point des connissances Floret Ch, Pontanier R (eds). IRD 2001; 21-83.
38. Fournier A. Cycle is the producer and producer of the whole family of herbes in soudaniennes pateurs: Les Jachères de la Région de Bondoukui (Burkina Fasso). Ecologie. 1994; 25(3): 173-188.
39. Hiernaux P, Fernández-Rivera S. Grazing Rotation in the annual-dominated range of the Sahel, in Eldridge et Freudenberger (eds).1999; 513-514.
40. Achard Fr, Hiernaux P, Banoin M. La jachère Fourragère naturelle et améliorée en Afrique de l'Ouest. In: Floret C, Pontanier R (eds). 2000; vol. II: 201-240.
41. Banoin M., Achard F. Sites, probables, researchers, premier résultats at Ticko et Bogodjotou, rapport, projections on the recourse and the gestion de la jachère en Afrique de l'Ouest, Faculté d'Agronomie, Niamey. 1997; 13p.
42. Da Costa EC Above-ground biomass accumulation in fallow fields at the Nhambita community, Mozambique. A dissertation presented for the degree of Master of Science, University of Edinburgh. 2005; 79p.
43. Kanmegne J, Smaling EMA, Nolte C, Ekwadi S, Doumbe JB. Effects of land-use changes on biomass, carbon and nutrient stock in the humid forest zone of Southern Cameroon. Kanmegne J. (Ed). Wageningen University Tropenbos International 2004; 35-48.
44. Lamotte M, Bourlière F. Problèmes d'écologie. Structure et Fonctionnnement des écosystèmes terrestres. Paris Masson 1978; 345p.
45. Manlay R, Masse D. Dynamique du carbone dans le cycle culture - jachère en Afrique de l'Ouest. In: Floret C (ed.). Raccourcissement du temps de jachère, biodiversité et développement durable en Afrque du Center et de l'Ouest. Rapport final Dakar CEE-Orstom nineteen ninety eight; 91-104.
46. Saïdou A, Balogoun I, Koné B, Gnanglè C, Aho N. Effett's système agroforestier à karité (Vitellaria paradoxa c.f. gaertn) sur le sol et le potentiel de production du maïs (Zea maize) en zone soudanienne du Bénin. Int. J. Biol. Chem Sci. 2012; 6(5): 2066-2082.
47. Anobla AOMM, Kassi N'Dja J. Dynamique de la végétation de Bamo et carbone dans la mosaïque de végétation. European Scientific Journal. 2016; 12 (18): 857-7881.
48. Manlay R. Dynamique de la mateère organique à l'échele d'un terroir agro-pastoral de savane ouest-africaine (Sud-Sénégal). Thèse de Doctorat, ENGREF, Ecole Nationale du Génie Rural, des Eaux et Forêts Center de Montpellier. 2000; 326p.

49. Palm CA, Woomer PL, Alegre J, Arevalo L, Castilla C, Cordeiro DG, Feigl B, Hairiah K, Kotto-Same J, Mendes A, Moukam A, Murdiyarso D, Njomgang R, Parton WJ, Rice A, Rodrigues V, Sitompul SM, Van Noordwijk M. Carbon Sequestration and Trace Gas emissions in slash-and-burn and alternative land uses in the humid tropics. Final Report, Alternatives to Slash and Burn (ABS). Climate Change Working Group, Phase II. ICRAF, Nairobi, Kenya 2000; 29p.
50. Simiane GV Evaluation of the carbone plantations of plantations agroforestières and databases of experts in the autonomous regions of Talamanca, au Costa Rica Mémoire de maîtrise en biologie végétale, Maître ès science, Faculty of Sciences de l'Agriculture et de l'Alimentation, Université Laval. 2007; 128p.
51. Gond V, Dubiez E, Boulogne M, Gigaud M, Péroches A, Pennec A, Fauvet N, Peltier R. Forest cover and carbon stock change dynamics in the Democratic Republic of Congo: Case of the wood-fuel supply basin of Kinshasa. Bois et forêts des tropiques 2016; 327 (1): 10 - 28.
52. Kaïré M. La production ligneuse des jachères and son utilization par l'homme. Thèse de doctorat, Université de Provence (Aix - Marseille 1), France 1999; 113p.
53. Masse D. Changements d'use de terres dans les agro-systèmes d'Afrique subsaharienne Proprietes des sols et dynamique des matières organiques. Institut National Polytechnique de Toulouse Ecole Nationale Supérieure Agronomique de Toulouse, Toulouse, France 2007; 82 p.
54. Nolte C, Kotto-Same J, Moukam A, Thenkabail PS, Weise SF, Zapfack L. Land use characterization and estimation of carbon stock in the alternative to slash and burn Benchmark area in Cameroon. Resource and crops management research monograph, 28. IITA, Ibadan. 2001; 83p.
55. San-José JJ, Montes R, Farinas MR. Carbon stocks and Fluxes in a temporal scaling for a savana to a semi-deciduous forest. Forest Ecology and Management 2000; 5: 251-262.
56. FAO Rapport sur les ressources en sols du monde 2002; 96p.

Table 1 : Geographical coordinates, altitudes and physical characteristics of fallow soil.

Site characteristics	**Fallow types**			
	F01	F02	F05	F20
Geographical	7°25'N et 13°33’E	7°25'N et 13°33’E	7°25'N et 13°33’E	7°25'N et 13°33’E

coordinates				
Altitude (m)	1093,75	1093,75	1089,75	1095,5
pH	7,52	7,25	8,56	8,09
Soil type	Ferralitic soil on basaltic mother			
Structure	Granular polyhedral			
Texture	Clayey			
Vegetation stratum	Herbaceous and Grasses	Herbaceous and Grasses	Herbaceous and grasses	Shrubs

Table 2: Specific composition of Ngaoundere savannah fallows, Cameroon

Family	**Species**	**BT**	**VT**	**F01**	**F02**	**F05**	**F20**
Poaceae	*Pennisetum pedicellatum* Trin.	AW	G	xx	xx	-	-
Poaceae	*Pennisetum polystachion* (L.) Schult.	AW	G	xx	xx	-	-
Poaceae	*Hyparrhenia involucrata* Stapf	AW	G	x	-	-	xx
Poaceae	*Eragrotis tremula* Hochst. ex Steud	AW	G	-	x	-	-
Cesalpiniaceae	*Senna tora* L.	AW	H	-	x	-	-
Acanthaceae	*Hypoëstes cancellata* Nees.	AW	H	-	x	-	-
Fabaceae	*Sesbania pachycarpa* DC.	AW	H	-	x	-	-
Fabaceae	*Indigofera tinctoria* L.	AW	H	-	-	xx	-
Fabaceae	*Crotalaria retusa* L.	AW	H	-	-	x	-
Rubiaceae	*Oldenlandia corymbosa* L.	AW	H	-	-	x	-
Euphorbiaceae	*Phyllanthus amarus* Schum. et Thonn.	AW	H	-	-	-	x
Euphorbiaceae	*Croton lobatus* L.	AW	H	-	-	-	x
Poaceae	*Eragrotis atrovirens* (Desf.) Trin. ex Steud.	PW	G	x	-	xx	-
Poaceae	*Andropogon gayanus* Kunth.	PW	G	-	x	-	xx
Rubiaceae	*Richardia brasiliensis* Gomez	PW	H	x	-	-	-
Malvaceae	*Sida rhombifolia* L.	PW	H	-	x	-	-
Sterculiaceae	*Waltheria indica* L.	PW	H	-	x	-	-
Fabaceae	*Stylosanthes guianensis* (Aubl.) SW.	PW	H	-	-	x	-
Amaranthaceae	*Aspilia kotchy* (Schultz Bip.) Benth. et Hook-f-mel.	PW	H	-	-	x	-
Tiliceae	*Triumfeta rhomboïdea* Jacq.	PW	H	-	-	x	-
Lamiaceae	*Nelsonia canescens* (Lam.) Spreng	PW	H	-	-	x	-
Caesalpiniaceae	*Piliostigma thoninngii* (Schum.) Mile-Redhead	LV	S	x	x	x	x
Combretaceae	*Terminalia glauscesens*	LV	T	x	x	x	x
Rubiaceae	*Gardenia aqualla*	LV	S	-	x	-	-
Annonaceae	*Annona senegalensis*	LV	S	-	-	x	x
Moraceae	*Ficus sycomorus*	LV	T	-	-	-	x
Guittiferaceae	*Harungana madagascariensis*	LV	S	-	-	-	x
Hymenocardiaceae	*Hymenocardia acida*	LV	S	-	-	-	x
Ochnaceae	*Lophira lanceolata*	LV	T	-	-	-	x
Myrsinaceae	*Maesa lanceolata* Forssk.	LV	S	-	-	-	x
Mimosaceae	*Parkia biglobosa*	LV	T	-	-	-	x
Clussiaceae	*Psorospermum febrifugum*	LV	S	-	-	-	x
Apiaceae	*Steganotaenia araliaceae*	LV	T	-	-	-	x
Myrtaceae	*Syzygium guineense*	LV	S	-	-	-	x

BT: biological type; VT: vegetation type; Annual weeds (AW), Perennial weeds (PW) et perennial woody (LV); Tree (T), Shrub (S), Herbacious (H) and grasses (G); Very present (xx); Present (x) et absent (-)

Table 3: Influence of the fallow age on the phytomass (t.ha^{-1}).

Fallows	Shrubs	Herbacious	Litters	Roots
F01	0.09 (0.03)a	7.85 (2.48)c	0.02 (0.01)a	2.57 (1.33)b
F02	0.20 (0.01)a	9.44 (4.13)d	0.05 (0.02)a	3.07 (1.11)c
F05	0.23 (0.18)a	12.42 (4.15)c	0.08 (0.02)a	3.78 (2.73)b
F20	0.39 (0.22)a	34.56 (3.39)c	0.23 (0.05)b	6.79 (4.20)b
F	1.22ns	38.24***	6l.48***	16.08***

ns: not significant; ***p<0.001. Standard deviation in parenthesis. Different letters of a same colon indicate that the values are significantly different. Fallow of one year old (F01), of two years-old (F02), of five years-old (F05) and of twenty years-old (F20).

Table 4 : Changes of fine root phytomass (t.ha^{-1}) in the fallows

Fallows	Soil depth (cm)		t *student*
	0-10	10-25	
F01	2.01 (0.90)a	0.56 (0.43)a	28.80***
F02	2.51 (0.66)a	0.56 (0.45)a	15.71**
F05	3.05 (2.14)a	0.73 (0.69)a	58.62***
F20	4.71 (3.22)a	2.08 (0.98)b	21.11***
F	4.04ns	12.04**	

ns: not significant; ** P < 0.01; *** P < 0.001. Standard deviation in parenthesis; Different letters of a same colon indicate that the values are significantly different. Fallow of one year old (F01), of two years-old (F02), of five years-old (F05) and of twenty years-old (F20).

Table 5 : Changes of carbon stock in the vegetation components and soil (tC.ha^{-1}).

Fallows	Shrubs	Herbaceous	Litter	Roots	Earthworm casts	Soil
F01	0.17 (0.14)	3.62 (1.14)a	0.70 (0.39)a	0.91 (0.42)a	2.10 (1.2)a	27.02 (5.2)a
F02	0.42 (0.03)	4.37 (1.97)a	1.68 (0.78)a	0.99 (0.35)a	6.12 (2.26)a	31.10 (3.67)a
F05	0.90 (0.19)	7.96 (2.99)b	6.46 (3.84)b	1.48 (1.10)b	51.32 (41.78)b	53.54 (16.14)b
F20	1.02 (0.19)	11.49 (1.64)c	12.80 (2.31)c	2.35 (1.45)c	63.30 (16.65)b	63.89 (28.22)c
F	1.22ns	39.70***	65.04***	15.11**	13.05**	79.32***

ns: not significant; ** P < 0.01; *** P < 0.001. Standard deviation in parenthesis; Different letters of a same colon indicate that the values are significantly different. Fallow of one year old (F01), of two years-old (F02), of five years-old (F05) and of twenty years-old (F20).

Table 6 : Changes of carbon stock (tC.ha^{-1}) in the fine roots

Soil depth (cm)	F01	F02	F05	F20	F
0-10	0.72 (0.32)a	0.81 (0.21)a	1.19 (0.83)a	1.69 (1.15)b	3.99*
10-25	0.19 (0.10)a	0.18 (0.14)a	0.29 (0.27)b	0.66 (0.30)c	11.34**
t-*Student*	15.83**	58.46***	20.90**	14.92**	

ns: not significant; ** P < 0.01; *** P < 0.001. Standard deviation in parenthesis; Different letters of a same line indicate that the values are significantly different. Fallow of one year old (F01), of two years-old (F02), of five years-old (F05) and of twenty years-old (F20).

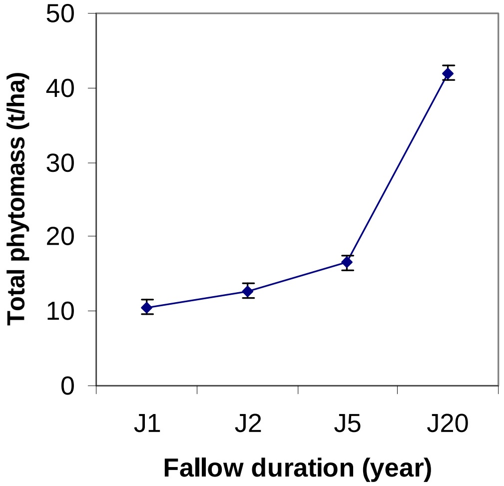

Figure 1 : Total phytomass according to fallow age (years) in sudano-guinea savannah of Ngaoundere Cameroon. Vertical bar indicates standard deviation.

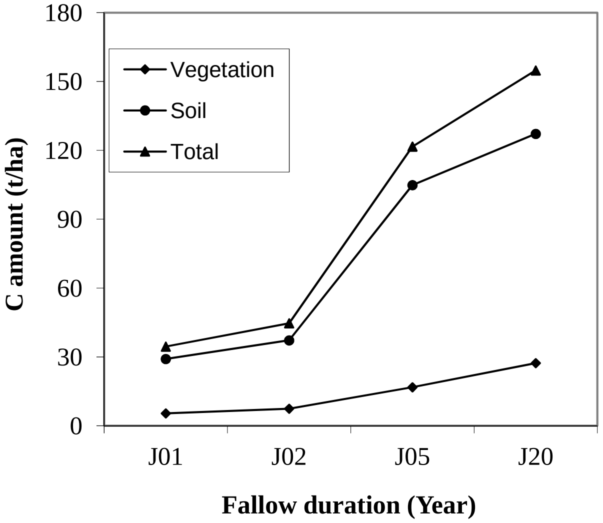

Figure 2 : Carbon amount (tC.ha^{-1}) in vegetation, soil and total according to fallow age (years) in sudano-guinea savannah of Ngaoundere Cameroon.