Original Research Article

Carbon Stock Assessment of Psiduim guayava L.(Myrtaceae) Agroforestry Systems in Septentrion Zone of Cameroon

ABSTRACT

The present study aims to quantify carbon storage in different biomass pools of Psidium guayava agroecosystems in the northern region of Cameroon in order to understand their contribution to climate change mitigation. The destructive and non-destructive methods were used according to a random complete Fisher block device with 4 repetitions. The results obtained show that the average total carbon stock of Psidium guayava agroecosystems in the northern zone of Cameroon is 44.44 ± 4.96 tC/ha. The total carbon stock varies by region; in the Adamawa region (46.30 ± 4.91 tC/ha); North (46.34 ± 4.93 tC/ha) and Far North (40.69 ± 4.98 tC/ha). These results show the considerable contribution of Psidium guayava agroecosystems in the fight against the mitigation of climate change in the Septentrion zone of Cameroon.

Keywords: Agroforestry systems, Cameroon, Carbon sinks, Climate Change, Psidium guayava.

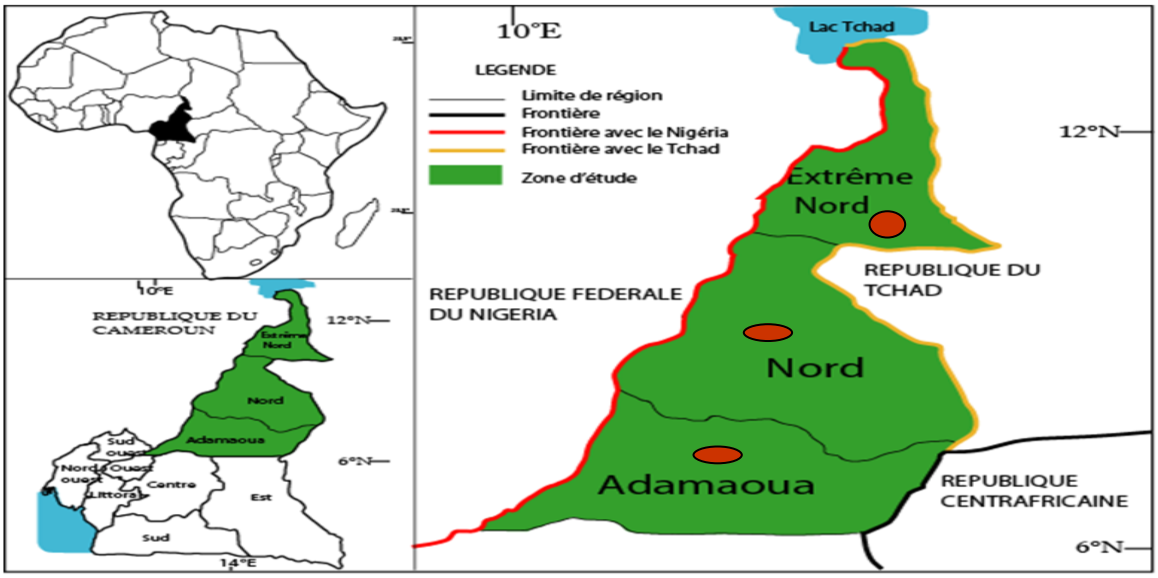
1. INTRODUCTION

Agroecosystems are major sources of fruit and medicinal products for local populations, especially during famine or in the event of natural disasters [1]. They are important for local communities and for the environment. They host a great diversity of natural resources [2]. The sustainable management of these agro-ecosystems appears to be a priority [3]. However, these environments have undergone major disturbances for several decades linked on the one hand to the natural aridity conditions, long dry season, strong evaporation, high spatio-temporal variability of low precipitation and on the other hand to an uncontrolled overexploitation of resources, which accentuate the deterioration of climatic conditions [4]. Several researchers have proposed agroforestry systems, a complex agricultural activity integrating trees into crops and or raising livestock [4]. In the eyes of researchers, this activity presents one of the solutions to reconcile agricultural production and environmental protection [2]. The guava tree is a fruit tree whose size varies between 3 and 8 meters in height [5]. It belongs to the Myrtaceae family and whose scientific name is Psidium guayava L. Native to Latin America, this tree is cultivated mainly for its fruit, but also for its leaves and bark, the uses of which are many and varied [5]. Indeed, they are rich in vitamin and sugar. These fruits are a source of income for sellers. On the pharmacopoeia plant, the leaves and bark of the guava root contain abundant substances which are used in the treatment of diarrhea and dysentery [6]. A leaf decoction applied in the form of a mouthwash and gargle heals inflammation of the oral mucosa and pharyngitis [7]. However, in the Sudano-Guinean and Sudano-Sahelian zone, particularly in Cameroon, knowledge on the carbon stock produced by Psidium guayava agroecosystems is very limited, even unavailable. However, the carbon stock informs a lot about the functioning, the ecological and economic productivity of agrosystems [8]. Understanding carbon stocks would improve the sustainable management of Psidium guayava agrosystems that can contribute to the resilience of rural populations to climate change. It would therefore be important to have sufficiently precise information on the carbon stocks present in all potential carbon sinks formally recognized, including those of Psidium guayava agroecosystems. Hence the interest in this work which will contribute to the conservation and preservation of Psidium guayava agroforestry systems for measures to mitigate the harmful effects of climate change.

2. MATERIALS AND METHODS

2.1 Study area

The study took place in northern Cameroon. It is the part of the country which, from an administrative point of view, covers three regions: Adamawa (Ngaoundéré), Far North (Maroua) and North (Garoua), which have 15 departments. Northern Cameroon is a space where the climate is the Sudano-Sahelian and Sudano-Guinean type (**Fig.1**).



Source fond de carte: Atlas de la province Extrême-Nord Cameroun, 2000

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Fig.1. Geographic location of the study area

2.2 Site selection criteria and experimental setup

The choice of study station was based on the availability, age, area and density of Psidium guayava plantations. Five Psidium guayava plantations were selected according to the different ages: (2 years; 4 years; 6 years; 8 years and 10 years). The experimental device installed is a complete random Fisher block with 4 repetitions. The three regions (Adamawa, North and Far North) are considered as main treatments; five Psidium guayava agroforestry systems of different ages (2 years; 4 years; 6 years; 8 years and 10 years) chosen in each region are considered as secondary treatments and the 4 plots of 50 m x 50 m as repetitions.

2.3 Data collection

Data were collected in quadrats 50 x 50 square meters (north-south) is 2500 m² surface were not installed in variable stand in the end make a comparison. Geographic coordinates were taken using the GPS for every tree that is part of the sample to determine its location on the ground. In 5 sub-quadrats established with the son and compass, all wood a CD (Collar diameter ≥ 5 cm were consistently measured and counted using a tape to 1.30 m above ground for large trees and 50 cm of soil for shrubs and bushes. It is to assess the biomass present in several components (aboveground and belowground), in addition to consider the soil organic matter. The living aboveground biomass: All trees having a greater diameter at breast height or equal to 10 cm are measured in the main plot of 2500 m^2. Biomass dead wood: two perpendicular lines 50 m intersecting at the center of the plot are drawn and the variables taken into effect were the case, the circumference, total height, and the status of the tree. Sampling dead wood was done in two categories: -For the dead timber, DBH was measured by making use of methods for living trees and the height was measured using the measuring tape. The diameters of trunks or branches fell to the ground and intercepting this line is measured using a caliper. Only diameters greater than 5 cm will then be considered in the analysis. Herbaceous and litter Biomass is collected in a square shaped metal frame 1m x 1m.

Soil samples are collected in May-June 2019. In each 500 m² survey, soil samples were taken from the 0.25 m x 0.25 m quadrats. Under each identified tree and under a clearing, the soil samples were taken at 0-30 cm deep at three different points in order to constitute composite samples. A total of 45 soil samples were taken (3 trees x 1 depth and 3 samples taken for the apparent density x 5 research areas). Each level of soil depth taken using a machine and a trowel is immediately put in a closed bag in a cooler, in the shade to avoid evaporation. All these samples were conditioned/dried in the open air at the pedology laboratory of the Faculty of Management of Natural Renewable Resources, International University of Central Africa (Cameroon). They were then milled and screened for later use in determining the organic carbon content of the soil. Another sampling of soil samples was done using a 196.25 cm^3 soil cylinder (5 cm diameter and 10 cm height) to determine bulk density. These samples were weighed using a precision scale and then placed in an oven at a temperature of 105 °C. They were then removed from the oven and placed in the desiccator for two hours for cooling before being weighed again. The dry weight obtained made it possible to determine the dry biomass and to deduce the organic carbon content of the soil then the soil organic carbon stock.

2.4. Estimate carbon stock

2.4.1 Aboveground biomass

The allometric equation developed by [9] was used to calculate the biomass of each individual and to deduce carbon in wood of the system studied. $AGB = 0.069xCD^{2.456}$ with AGB: Aboveground biomass in kilogram (kg), CD: Collar Diameter (cm). From this biomass, the amount of carbon (tC/ha) is obtained by multiplying this biomass by 0.475 conversion factor [10]; then it is converted to tons of carbon per ha.

2.4.2 Dead wood biomass

The calculation of the volume of dead timber was done thanks to the formula used by [11, 12] as follows: $V = \pi * h * f *(DBH/2)^2$ where V: Volume of death timber (m^3); DBH: Diameter Breast Height (m); h: height of death timber (m); f = form factor (0.627). The lying on the dead wood biomass was measured using the line intersect method presented by [12, 13]. Calculating the volume of the coated dead wood was done using the formula used by [14] as follows: $V= \pi^2 (\Sigma di^2) / 8L$ with V: volume of wood density (m^3/ha); Di: diameter of each wood debris sampled (m); L: length of the quadrant (m) = 50 m in the case of our study. Translating the results obtained from the bulk volume was made by setting the value of wood density to 0.47 KgMS.m^{-3} [8]. The portion of the dry mass of carbon stock is made by the following equation: Carbon stock in dead wood = Quantity of dry matter (DM) x 0.5 [15].

2.4.3 Herbaceous and litter Biomass

The herbaceous and litter were dried in an oven at 65 °C for 72 hours and then ground and the organic carbon was determined using dry ashing method. Equation (A): $DM =(PSE/PHE) *100$ where DM = percentage of dry matter (%); PSE = dry weight of the sample after three days in the oven at 65 °C (g); PHE=wet weight of the sample measured in the field (g). Equation (B): $B= (PHT*DM)/100$; where: B = biomass (g); PHT = Total wet weight in measured in the field (g); DM = percentage of dry matter (%) [8, 15].

2.4.4 Roots biomass

The calculation of the roots biomass was done thanks to the formula developed by [9] as follows: Roots biomass=$0.019x\ CD^{2.496}$ where CD: Collar Diameter.

2.4.5 Soil organic carbon

It was determined following by [16] method which consists to oxidize soil organic matter with potassium bicarbonate ($K_2Cr_2O_7$) in sulfuric acid medium (H_2SO_4) in a sol/$K_2Cr_2O_7$ ratio of 0.25/10. The assay was done by calorimetry. The organic content was determined by multiplying the organic carbon content by Sprengel factor which is 1.724 for cultivated soils and 2 for non-crop land. Soil carbon (SCOS) (tC/ha) = Da. (% COS). S. P [17] with Da: bulk density in tones/m^3; %COS: organic carbon content of the soil; S: area in m^2; p: depth m.

2.4.6 Total carbon

CT = AGB + CR + CL + CH+ CBM + SCOS with CT: Total Carbon; AGB: Carbon in aboveground biomass; CR: Carbon in roots biomass; CL: Litter carbon; CH: Herbaceous Carbon; CBM: carbon dead wood; SCOS: Soil carbon.

2.5 Data analysis

The data was encoded in the EXCEL and analyzed using the Statgraphics plus 5.0. The significance and correlation tests were performed software through ANOVA and Duncan test at 5 %.

3. Results

3.1 Carbon in aboveground biomass

The 10-year plots sequester more carbon in aboveground biomass in the three regions studied. Between the three regions, in Adamawa's 10-year plots sequester carbon in aboveground biomass. Duncan's test attests to a significant variation in the carbon contained in the aboveground biomass between the different plots in Adamawa (F = 10.15; P = 0.000), North (F = 9.05; P = 0.002) and Far North (F = 10.42; P = 0.000) (Table 1).

Table1. Carbon in aboveground biomass

Age (years)	Adamawa	North	Far North	Mean
2	4.54 ± 0.34a	3.65 ± 0.21a	1.54 ± 0.12a	3.24 ± 0.21
4	5.04 ± 0.23a	4.65 ± 1.45a	3.98 ± 0.24a	4.55 ± 0.65
6	7.14 ± 1.21ab	8.02 ± 5.76ab	6.93 ± 0.37ab	7.36 ± 1.32
8	8.88 ± 3.12b	9.65 ± 3.69b	7.67 ± 1.43b	8.73 ± 3.52
10	10.87 ± 6.11c	10.54 ± 6.34c	9.43 ± 5.43c	10.28 ± 6.87
Mean	7.29 ± 4.54	7.30 ± 4.61	5.91 ± 2.43	6.83 ± 2.32

The assigned values of the same letter are not statistically different (p> 0.05; Duncan's test).

3.2 Carbon in herbaceous biomass

Duncan's test does not show any significant variation in the carbon contained in herbaceous biomass between the different plots in Adamawa (F = 0.15; P = 0.548), North (F = 0.17; P = 0.524) and Far North (F = 0.12; P = 0.432). The 2-year plots sequester more carbon in herbaceous biomass of the three regions studied. In Adamawa, 2-year-old plot contains the largest carbon stock in herbaceous biomass (Table 2).

Table 2. Carbon in herbaceous biomass

Age (years)	Adamawa	North	Far North	Mean
2	3.44 ± 0.16a	3.34 ± 0.12a	3.29 ± 0.11a	3.35 ± 0.14
4	3.38 ± 0.11a	3.24 ± 0.13a	3.22 ± 0.10a	3.28 ± 0.11
6	3.33 ± 0.14a	3.21 ± 0.12a	3.06 ± 0.10a	3.20 ± 0.12
8	3.29 ± 0.10a	3.15 ± 0.11a	3.03 ± 0.11a	3.15 ± 0.10
10	3.23 ± 0.12a	3.04 ± 0.10a	3.00 ± 0.10a	3.09 ± 0.11
Mean	3.33 ± 0.14	3.19 ± 0.12	3.12 ± 0.11	3.21 ± 0.14

The assigned values of the same letter are not statistically different (p> 0.05; Duncan's test).

3.3 Carbon in litter biomass

Duncan's test does not show any significant variation in the carbon contained in litter biomass between the different plots in Adamawa (F = 0.10; P = 0.604), North (F = 0.13; P = 0.728) and Far North (F = 0.14; P = 0.744). The 10-year plots sequester more carbon in litter biomass of the three regions studied. The Adamawa, 10-year plot contains the largest carbon stock in litter biomass (Table 3).

Table 3. Carbon in litter biomass

Age (years)	Adamawa	North	Far North	Mean
2	2.21 ± 0.11a	2.05 ± 0.11a	2.00 ± 0.11a	2.08 ± 0.10
4	2.24 ± 0.11a	2.15 ± 0.11a	2.03 ± 0.11a	2.14 ± 0.11
6	2.29 ± 0.10a	2.21 ± 0.10a	2.06 ± 0.10a	2.18 ± 0.12
8	2.33 ± 0.12a	2.25 ± 0.11a	2.11 ± 0.11a	2.23 ± 0.10
10	2.34 ± 0.10a	2.34 ± 0.10a	2.22 ± 0.10a	2.30 ± 0.11
Mean	2.28 ± 0.11	2.20 ± 0.11	2.08 ± 0.11	2.18 ± 0.11

The assigned values of the same letter are not statistically different (p> 0.05; Duncan's test).

3.4 Carbon in deadwood biomass

In Adamawa, 10-year plots contain the largest carbon stock in dead wood biomass. In contrast, in the North region, 6-year plots sequester more carbon in dead wood biomass. And finally in Far North region, 8-year-old plots store more carbon in dead wood biomass. Duncan's test does not show any significant variation in the carbon contained in dead wood biomass between the different plots in Adamawa (F = 0.35; P = 0.848), North (F = 0.57; P = 0.924) and Far North (F = 0.22; P = 0.532) (Table 4).

Table 4. Carbon in deadwood biomass

Age (years)	Adamawa	North	Far North	Mean
2	0.44 ± 0.01a	0.64 ± 0.04a	0.29 ± 0.00a	0.45 ± 0.01
4	1.38 ± 0.03a	0.44 ± 0.01a	0.22 ± 0.00a	0.68 ± 0.02
6	1.33 ± 0.02a	3.21 ± 0.10b	0.76 ± 0.01a	1.76 ± 0.12
8	0.29 ± 0.00a	1.15 ± 0.02a	1.03 ± 0.02a	0.82 ± 0.03
10	3.03 ± 0.11b	1.04 ± 0.01a	0.86 ± 0.01a	1.64 ± 0.12
Mean	1.29 ± 0.04	1.29 ± 0.04	0.63 ± 0.01	1.07 ± 0.05

The assigned values of the same letter are not statistically different (p> 0.05; Duncan's test).

3.5 Carbon in roots biomass

Duncan's test attests to a significant variation in the carbon contained in root biomass between the different plots in Adamawa (F = 4.15; P = 0.048), North (F = 6.17; P = 0.024) and Far North (F = 4.52; P = 0.032). The 10-year plots sequester more carbon in root biomass in the three regions studied. The Adamawa 10-year plot contains the largest carbon stock in root biomass (Table 5).

Table 5. Carbon in roots biomass

Age (years)	Adamawa	North	Far North	Mean
2	1.32 ± 0.12a	1.08 ± 0.06a	0.98 ± 0.03a	1.12 ± 0.08
4	1.44 ± 0.16a	1.34 ± 0.13a	1.24 ± 0.10ab	1.34 ± 0.17
6	1.97 ± 0.21ab	2.18 ± 0.23ab	1.91 ± 0.21b	2.02 ± 0.19
8	2.38 ± 0.31b	2.57 ± 0.32b	2.17 ± 0.28bc	2.37 ± 0.23
10	2.85 ± 0.43bc	2.77 ± 0.52bc	2.68 ± 0.32c	2.76 ± 0.25
Mean	1.99 ± 0.23	1.98 ± 0.25	1.79 ± 0.21	1.92 ± 0.26

The assigned values of the same letter are not statistically different (p> 0.05; Duncan's test).

3.6 Soil organic carbon

The Soil organic carbon is higher in the 10-year plots in the three regions studied. In Adamawa, 10-year-old plot has the largest soil carbon stock. Duncan's test attests to a significant variation in soil organic carbon between the different plots in Adamawa (F = 8.58; P = 0.028), North (F = 7.75; P = 0.014) and Far North (F = 5.52; P = 0.011) (Table 6).

Table 6. Soil organic carbon (0-30 cm)

Age (years)	Adamawa	North	Far North	Mean
2	21.29 ± 3.87a	20.34 ± 3.23a	19.89 ± 1.94a	20.17 ± 2.04
4	28.22 ± 4.11ab	26.24 ± 3.86ab	25.38 ± 2.87ab	26.61 ± 2.88
6	30.16 ± 5.32b	33.21 ± 5.52b	28.33 ± 3.04b	30.56 ± 3.65
8	32.83 ± 5.86b	35.15 ± 5.76b	28.74 ± 3.32b	32.24 ± 4.21
10	38.04 ± 6.23c	36.84 ± 7.84c	33.23 ± 5.02c	36.03 ± 4.75
Mean	30.10 ± 5.38	30.35 ± 5.75	26.91 ± 4.89	29.12 ± 5.01

The assigned values of the same letter are not statistically different (p> 0.05; Duncan's test).

3.7 Total carbon stock

The total carbon stock is more significant in the 10-year plots in the three regions studied. In Adamawa, 10-year plot contains the largest total carbon stock. Duncan's test attests to a significant variation in the total carbon stock between the different plots in Adamawa (F = 10.5; P = 0.000), North (F = 8.17; P = 0.004) and Far North (F = 3.02; P = 0.012) (Table 7).

Table 7. Total carbon stock

Age (years)	Adamawa	North	Far North	Mean
2	33.24 ± 3.88a	31.10 ± 4.14a	27.99 ± 3a	30.77 ± 3.87
4	41.70 ± 4.54b	38.06 ± 3.87ab	36.07 ± 3.32ab	38.61 ± 4.03
6	46.22 ± 4.87b	52.04 ± 5.02b	43.05 ± 4.03b	47.10 ± 4.23
8	50 ± 4.88c	53.92 ± 5.43c	44.75 ± 4.12b	49.55 ± 4.97
10	60.36 ± 5.65d	56.57 ± 5.65d	51.59 ± 5.24c	56.17 ± 5.12
Mean	46.30 ± 4.91	46.34 ± 4.93	40.69 ± 4.98	44.44 ± 4.96

The assigned values of the same letter are not statistically different (p> 0.05; Duncan's test).

4. DISCUSSION

The 10-year plots sequester more carbon in the aboveground biomass in the three regions studied. Several factors could explain the spatial variability of carbon stocks noted at the level of different plots and zones studied. Gourlet-Fleury et al. [18], emphasize the influence of soil type on the spatial variability of biomass stocks, and therefore of their carbon in tropical areas. Our results are in the range 7 and 25 tC/ha estimated by Bello et al. [19] in agroforestry system. But these are lower than those of Rathore et al. [9] in North-Western Himalayas, India. Generally, the undergrowth grasses of 2-year-old plots stored more carbon compared to the undergrowth grasses of other plots of various ages. This is explained by the fact that the closure of older plots negatively influences the carbon reservoir of the herbaceous layer. Our results obtained are similar to that found by Kooke et al. [20] in 12-year-old, 4-year-old Acacia auriculiformis plantations; 2.5 years; 6 years and 2 years with 3.08 ± 0.04 tC/ha respectively; 3.13 ± 0.02 tC /ha; 3.16 ± 0.03 tC/ha; 3.07 ± 0.03 tC /ha and 3.16 ± 0.01 tC/ha and in Terminalia superba plantations (3.13 ± 0.03 tC/ha) in southern Benin. However, they remain above the range 0.25 ± 0.002 to 1.25 ± 0.002 tC/ha reported by Awe et al. [8] in Tectona grandis Agroforestry Parkland (Northern Region Cameroon). The 10-year plots sequester more carbon in the biomass of the litter in the three regions studied. These results are close to those obtained by [21] who estimates the carbon content of dead organic matter (litter) at 2.8 tC/ha and that this can vary between 2 to 3 tC/ha. This result is in the range between 0.16 and 3.26 tC /ha obtained by Mohanraj et al. [22] in India and 2.1 to 3.2 tC/ha obtained by [23] in Costa Rica. The reason why the Psidium guayava plots in the three regions store less carbon in the dead wood biomass is certainly due to the fact that farmers are very involved in these types of systems where dead trees are most often harvested (for ends of firewood). These results are in the range of 0.003 to 33.5 tC / ha reported by Bocko et al. [24] in the swamp forests of Likouala (North Congo) and in the range between 0.14 ± 0.02 to 8.92 ± 3.65 tC / ha reported by Awe et al. [12] in Northern Region Cameroon. But remain below the interval between 5.65 ± 0.01 to 9.97 ± 0.06 tC / ha reported by Awe et al. [8] in Tectona grandis Agroforestry Parkland (Northern Region Cameroon). The 10-year plots sequester more carbon in the root biomass in the three regions studied. This is explained by these great rooting abilities and the type of soil. These depths correspond to those from which these soils contain a negligible amount of fat. This leads us to conclude that root biomasses have many advantages in nutrient and carbon accumulation as shown in previous studies [25]. These results are far inferior to those obtained by Awe et al. [4]. The soil organic carbon is higher in the 10-year plots in the three regions studied. This could be explained mainly in part by the different textures and biochemical compositions of the soils. The average soil carbon stock of Psidium guayava agroecosystems in the northern region of Cameroon is 29.12 ± 5.01 tC /ha. This result is lower than those estimated by [21] which is 31 tC/ha for the dry tropical zones; Palm et al. [26] in agroforestry system based on cocoa which is 42 tC/ha and those obtained by Awé et al. [4] in stands with Khaya senegalensis (132.16 ± 16.34 tC/ha); to Burkea africana (101, 42 ± 10 tC/ha), to Anogeissus leiocarpus (84.67 ± 3.12 tC/ha) and to Piliostigma reticulatum (60.46 ± 5.23 tC/ha) in Northern region Cameroon. The total carbon stock is more significant in the 10-year plots in the three regions studied. According to [27], the more the tree grows, the more it sequesters carbon. The average total carbon stock of Psidium guayava agroecosystems in the northern zone of Cameroon is 44.44 ± 4.96 tC/ha. According to [28], the carbon storage capacity of an agroforestry system varies between 12 and 228 tC/ha with an average value of 95 tC/ha. The value obtained in our study is included in this range. Indeed, the amount of carbon sequestered by the agroforestry system largely depends on the cropping system put in place, on the structure and function of the latter [29, 30].

5.CONCLUSION

The present work was carried out to provide basic data for better conservation and enhancement of Psidium guayava agroecosystems in septentrion zone of Cameroon for order to better understand their contributing role in mitigating the harmful effects of global warming. The dynamics of biomass accumulation in forest stands is central to the carbon balance. Carbon sequestration rates in biomass and soil reservoirs determine the ability of Psidium guayava agroecosystems to remove carbon from the atmosphere. The results confirm that indeed, the concentration of Carbon in different pools of Psidium guayava agroecosystems studied is significantly important. These results show that, Psidium guayava agroecosystems are carbon reservoirs, because they have a good capacity to store carbon from the atmosphere. To realize the potential of the forest sector in septentrion zone of Cameroon, carbon sequestration must be integrated into the carbon trading system of the Kyoto Protocol's Clean Development Mechanism (CDM).

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