International Journal of Sciences

Research Article Volume 9 – February 2020 (02)

Carbon Sequestration Potential of Shea Trees (*Vitellaria paradoxa* C.F. Gaertn.) in Parklands under Two Soil Types (Ferralsol and Cambisol) in Northern Côte d'Ivoire

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Abstract: This study was conducted to assess carbon sequestration potential of shea trees in four shea parks in Northern Côte d'Ivoire to fight against climate change. The methodology used consisted in the delimitation of 2 ha of plot in shea parkland located in Ferkéssédougou, Ouangolodougou, Boundiali and Tengrela. On each plot delimited within these parklands, forests inventories were carried out and stem diameter at 1.30 m aboveground (DBH ≥ 5 cm) of the shea trees were measured. The dendrometric data collected made it possible to elaborate the structure of the shea trees in parkland, to estimate the biomass and the stocks of sequestered carbon. The results showed that shea populations, irrespective of the study site, showed a "reversed J" diameter distribution with decreasing individuals. The spatial distribution of the population of shea trees in Boundiali and Ferkéssédougou parklands is regular while it is aggregative in Ouangolodougou and Tengrela parklands. The spatial distribution of shea trees depends on the type of soils. Of all the sites that are mostly bushy savannas, sequestered CO_2 equivalents are high: 70.83 t.ha^{-1} at Boundiali, 49.47 t.ha^{-1} at Ferkéssédougou, 215 t.ha^{-1} at Ouangolodougou and 130 t.ha^{-1} at Tengrela. This study shows that agroforestry is to be promoted in Northern Côte d'Ivoire through the protection of shea tree parklands that limit greenhouse gas emissions in the atmosphere, especially in Northern Côte d'Ivoire. This will certainly facilitate Côte d'Ivoire's access to the carbon market.

Keywords: Shea Tree, Parklands, Soils, Carbon Stock, Northern Côte d'Ivoire

Introduction

Recent increases in greenhouse gas concentrations in the atmosphere appear to be changing the global climate, and future planned increases should continue this trend. An important strategy for slowing anthropogenic climate change is the sequestration of carbon dioxide (CO_2) from the atmosphere by increasing the carbon stocks of landscapes (Luedeling and Neufeldt, 2012). Agroforestry, an association of trees with crops or pastures, can be a sustainable alternative to deforestation and shifting cultivation, a cropping system still widespread in the tropics. Agroforestry is recognized as an activity capable of sequestering carbon as part of reforestation and planting measures. This greater fixation potential comes from better capture and resource use efficiency, compared to monoculture systems (Montagnini and Nair, 2004). In the semi-arid regions of West Africa, most subsistence farmers regard trees as an integral part of the cropping system. The trees in the agroforestry parks provide both traditional medicines and basic staple foods, including a wide variety of gums, oils, proteins, fruits and beverages, with important nutritional functions for many people, including particularly in rural areas (Ræbild *et al.*, 2011).

Agroforestry parks, particularly those of shea tree (*Vitellaria paradoxa* C.F. Gaertn.), are also a significant source of wood products, from which households derive a large part of their income and which are appreciable for local economies (Gnangle, 2012). Agroforestry systems in semi-arid areas of West Africa can store substantial quantity of carbon, but little attention has been given to the potential of carbon sequestration in shea parklands especially in Northern Côte d'Ivoire. The present study aims to contribute to the knowledge of the quantities of carbon sequestered in four shea tree parklands in a perspective of fight against climate change. The specific objectives are to determine spatial distribution of shea trees in parklands under soil types and to estimate the biomass and carbon sequestration potential of some shea parklands.

1. Material and methods

1.1. Study sites

The study was conducted in four shea parklands located at Ferkéssédougou and Ouangolodougou

Published at: http://www.ijsciences.com/pub/issue/2020-02/
DOI: 10.18483/ijSci.2265; Online ISSN: 2305-3925; Print ISSN: 2410-4477

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departments in the district of Tchologo, and at Boundiali and Tengrela departments in Bagoué district (**Figure 1**). These two districts and four department are located in Northern Côte d'Ivoire between longitude 5 °11 'and 6 ° 29' West and latitude 9 ° 31 'and 9 ° 35' North.

1.2. Plant material and soil samples

The biological material used for this study consists of the population shea trees existing in parklands. Soil samples were taken from open profiles in each shea park.

1.3. Soil characterization

The area chosen for the study, whose choice was inspired by the laws of horizontal or latitudinal zonality, as well as those of the vertical zones, made it possible to determine, an azimuthal direction according to which a line was opened to reach the most low. The topographic survey was possible thanks to a Garming Global Position System (GPS). The soil profiles were subsequently described according to the "ORSTOM" approach inspired by the method of Boulet and al. (1982). Soil samples were collected from the pits on each channel at the depths (0-20 cm), (20-40 cm) and (40-60 cm).

1.4. Analysis of the spatial structure of shea trees in parklands

Quadrat method describe in detail by Canard *et al.* (2004) was used to determine the spatial structure of shea trees in each park. It consisted of covering K-shaped study sites with regular shapes. The considered shea trees were represented as points after geo-positioning with GPS and the waypoints performed by the Arcgis software. The average number of points per mesh is equal to D = N / K. At each mesh i has been associated a number Di of points that it contains. Then the variance VD was calculated in order to deduce the Distribution Index (DI) whose formula is as follows:

$$DI = \frac{VD}{D}$$

The values obtained have been interpreted according to:

DI ≈ 1: random distribution (Poisson's law)
DI > 1: rather aggregative distribution
DI <1: rather regular distribution

1.5. Density of shea tree in parkland

The density (N), of all species combined, is the number of stems of diameter at breast height (DBH) ≥ 5 cm per unit area (Dotchamou *et al.*, 2016). It translates land use by species. Above all, it must be ensured that sampling is sufficient, ie that the area considered is large enough for the average density to be stabilized (Pascal, 2003). This parameter was calculated for each site using the equation below:

$$N = \frac{n\,x\,10000}{S}$$

Where n is the number of feet counted (dbh≥ 5 cm) and S the area (m^2).

1.6. Basal area of shea trees

The basal area is the area occupied by the trunk at breast height or 1.30 m above the ground. The basal area is the sum of the basal areas of all V. Paradoxa individuals, the results of which were reduced to the hectare. The basal area was estimated following formula:

$$G = \frac{Ci^2}{4\,\pi}$$

Where G the basal surface of an individual and Ci circumference of the individual i.

1.7. Estimation of carbon and atmospheric CO_2 equivalent stocks

1.7.1. Aerial biomass

The estimation of the above-ground biomass of shea trees in the plot is based on the allometric models of Chave *et al*. (2005) and Djomo *et al*. (2010). The aboveground biomass (BA) corresponds to the mass of dry plant matter per unit area and is divided into biomass of the trunk and biomass of the crown (branches). To calculate the biomass in forests, the existing calculation models are of two types: allometric models and wood volume models. In this study, we chose wood volume models. The aboveground biomass was thus calculated with the following formula:

$$BA = e^{[-2{,}187+0{,}916\,\ln(\rho HD^2)]}$$

Where D = diameter at breast height (m); ρ = specific density of the wood (t. m^3 dried at 103°C); H = total height of the shea tree (m).

1.7.2. Underground biomass

The estimate of root biomass in standing shea trees was evaluated using the method outlined in the guidelines established by the Intergovernmental Panel on Climate Change (IPCC, 2006). According to the latter, the equivalence in root biomass of standing trees is found by multiplying the value of the aboveground biomass by a coefficient R (stem / root ratio) whose value is estimated at 0.24. Thus, the underground biomass (UB) represents the root biomass of standing trees. It is calculated from the following formula:

$$BS = e^{(-1{,}0587+0{,}8836\,\ln(BA)}$$

1.7.3. Total Biomass

The total biomass of each shea tree (TB) is the sum of its above ground biomass and its underground biomass.

$$TB = AB + UB$$

1.7.4. Carbon stock

The carbon stock is calculated by multiplying the total biomass by a conversion factor (CF).

$$SC = TB \times 0.47$$

Where default carbon ratio of all species combined CF is 0.47

1.7.5. Atmospheric CO_2 equivalent stock

With regard to the sequestered atmospheric CO_2 stock, it is recognized that the atomic mass of Carbon is 12 and the one Oxygen is 16. Consequently, the molecular mass of CO_2 is 44. Thus, the ratio of the combination of carbon (C) and oxygen (O_2) is 3.67. The equivalent atmospheric CO_2 stock (tCO_{2eq}) is estimated by multiplying the carbon stock from biomass by 3.67.

$$tCO_{2eq} = SC \times 3.67$$

1.8. Data analysis

The ArcGIS software was used for the representation of the device in the plot. Dendrometric parameters of field-collected on shea trees in parkland were captured and compiled using Microsoft EXCEL 2007 for treatment, biomass calculation, and sequestered carbon. Comparison of stand diameter parameters was statistically processed by ANOVA 1 analysis with SPSS software version 20 (IBM Corp., USA). Whenever a significant difference is revealed, the ANOVA is supplemented by the TUKEY test, which identifies the variable (s) that is (are) significantly different from the other (s). The normality of the data and the homogeneity of the variances were checked beforehand using the Kolmogorov-Smirnov and Shapiro-Wilk tests, respectively.

2. Results

2.1. Morphological characteristics of soils under shea parklands

2.1.1. Soil under shea parkland at Boundiali

The dominant soil observed and described at the Boundiali site is moderately depth (up to 60 cm), has good organic matter impregnation at the level of the wet-surface horizons, with numerous sub-horizontal, decimetric, centimetric and millimeter roots. The surface horizons are porous, furniture with a polyhedral structure with a lumpy tendency at the root level. The texture is predominantly sandy-clay-silty, with about 20 to 25% clay. Median horizons are brown (10 YR 6/6) speckled ocher rusty (7.5 YR 6/8). They are apparently non-humus, fresh and have a sandy-clay texture (50 - 55% clay). Their sub-angular polyhedral structure is induced by coarse elements. They are not very porous with some millimeter roots of subhorizontal orientation and a class of drainage of the order of 5.3. An indurated layer was observed in medium depth. It is in the 2014 WRB classification, at the top of the slope of a Ferralic Cambisol (Ferric) and half-slope of a Dystric Cambisol (Ferric).

2.1.2. Soil under shea parkland at Ferkessedougou

In Ferkessédougou, the morphological description of the soils of the delimited site made it possible to observe, in mid-slope, profiles with heavy loads in coarse elements. Mid-slope soils have a depth of about 20 cm due to an indurated layer while those of the lower slope are deep and can reach 120 cm. The colors are mostly brown to ocher in the surface horizons and ocher to red in the depth horizons. The texture is sandy-clay-loam with about 11 to 25% clay in the surface horizons. In the depth horizons the clay content varies from 55 to 60%. The types of soil encountered are: Ferralic Cambisol (Ferric) at the upper third of the mid slope, Ferralic Cambisol (Colluvic) at the mid-slope and Plinthic Cambisol (Arenic) at the lower slope.

2.1.3. Soil under shea parkland at Ouangolodougou

The soil observed and described at the Ouangolodougou site is deep (up to 120 cm), with wet humeral penetration, with numerous subhorizontal decimetric to centimetric roots at the level of the surface horizons. The texture is predominantly sandy - clay - silty, with about 20 to 25% clay at the level of the surface horizon. The horizons, medians and depths have a clay-sandy-loamy texture. Medium to low porosity is observed. There is a good inking of plant roots at the level of the profile. Most of these are Pisoplinthic Ferralsol (Colluvic) in mid-slope and downstream Plinthic Ferralsol (Arenic).

2.1.4. Soil under shea parkland at Tengrela

At the bottom of the slope, the surface horizons are ocher brown, fresh, with many decimetric, centimetric and millimeter roots of subhorizontal orientation. The texture is sandy-clay-silty on the surface. The deep layer has a greyish mottled, rusty, apparently non-humus, fresh, sandy-clay-silty (25-30% clay) brown coloration. It has a polyhedric structure with a lumpy tendency at the root level, coherent to loose, slightly porous with some millimetric and centimetric roots of subhorizontal orientation. In this layer, drainage is good (drainage class: 2.8). This is a Plinthic Ferralsol (Arenic).

2.2. Total seedlings and adult plants inventoried on 2 ha delimited per site

The Ouangolodougou site recorded more seedlings (233 plants) compared to other sites. A total of 165 seedlings in Boundiali, 82 seedlings in Ferkéssédougou and 71 seedlings in Tengrela were registered. At the level of adult trees, of the 2 ha surveyed, the Ouangolodougou site has more (75 adult trees) compared to other sites including 40 adult trees in Tengrela, 30 in Ferkéssédougou and 18 in Boundiali. Using a "young plants / adult trees" ratio, the Boundiali site gives 1 adult tree for 9 young plants against 1 adult tree for 3 young plants at the Ouangolodougou site, in Ferkéssédougou 1 adult tree for 3 young plants, finally in Tengrela 1 adult tree for 2 young plants (Figure 2).

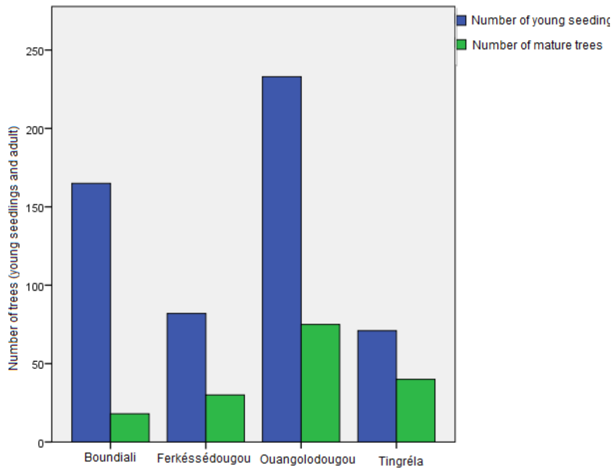

Figure 2: Total of seedlings and adult of shea trees evaluated per site

2.3. Spatial distribution of adult shea trees

The Figures 3 to 6 indicate the spatial distribution of adult shea trees associated with seedlings. The distribution index of adult trees varies between 0.694 and 3.95. The Boundiali site scored the highest value while the lowest value is observed at the Ouangolodougou site. The values obtained reflect an aggregate distribution of trees at the sites of Boundiali and Ferkéssédougou and a regular distribution of these at the Ouangolodougou and Tengrela sites (Table 1). On the Cambisols sites of Boundiali and Ferkéssédougou the observed spatial distribution is of regular type, whereas on the Ferralsols, sites of Ouangolodougou and Tengrela the spatial distribution is of aggregative type.

Table 1: Distribution index of adult shea trees

Sites	Average number of trees per mesh (D)	Variances (VD)	Distribution Index(DI)	Type of spatial distribution
Boundiali	0.56	2.24	3.95	aggregative
Ferkessédougou	0.96	1.00	1.04	aggregative
Ouangolodougou	3.47	0.82	0.26	regular
Tengrela	1.52	1.05	0.69	regular

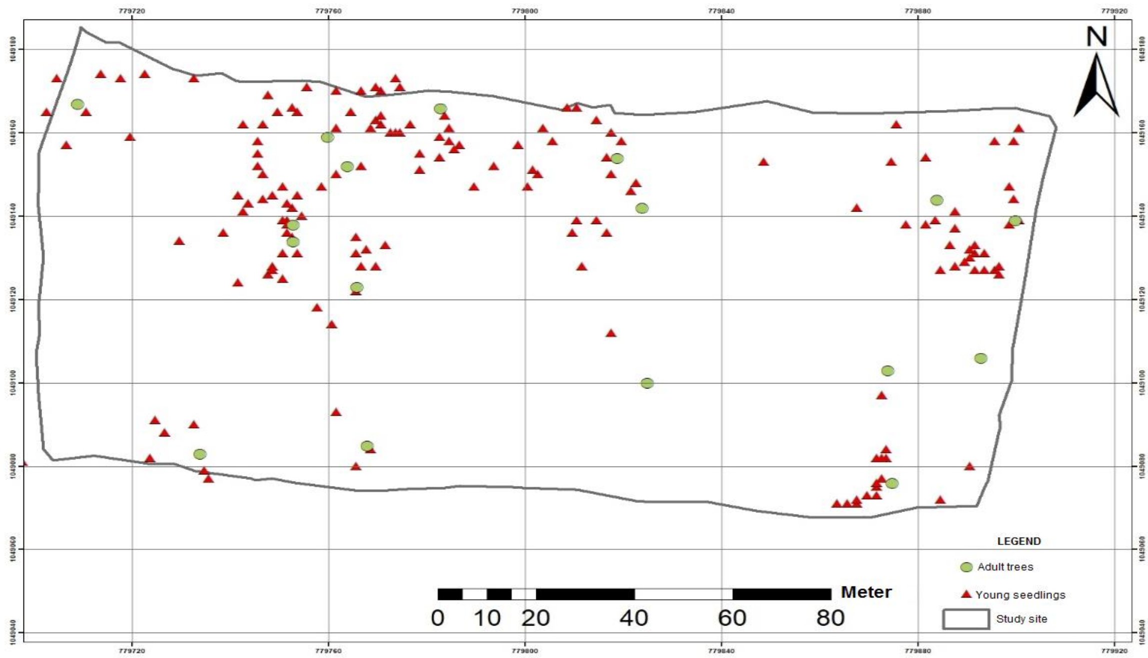

Figure 3: Spatial distribution of adult trees associated with shea seedlings in the Boundiali shea parkland

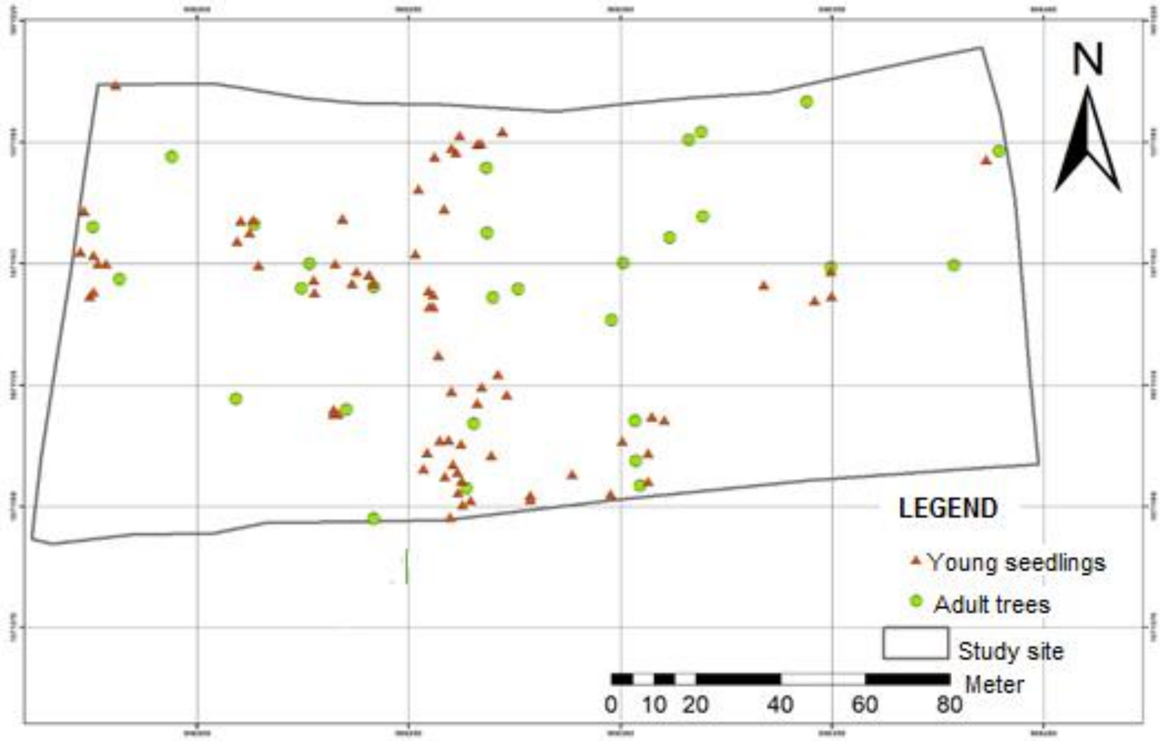

Figure 4: Spatial distribution of adult shea trees associated with shea seedlings in the Ferkessedougou shea parkland

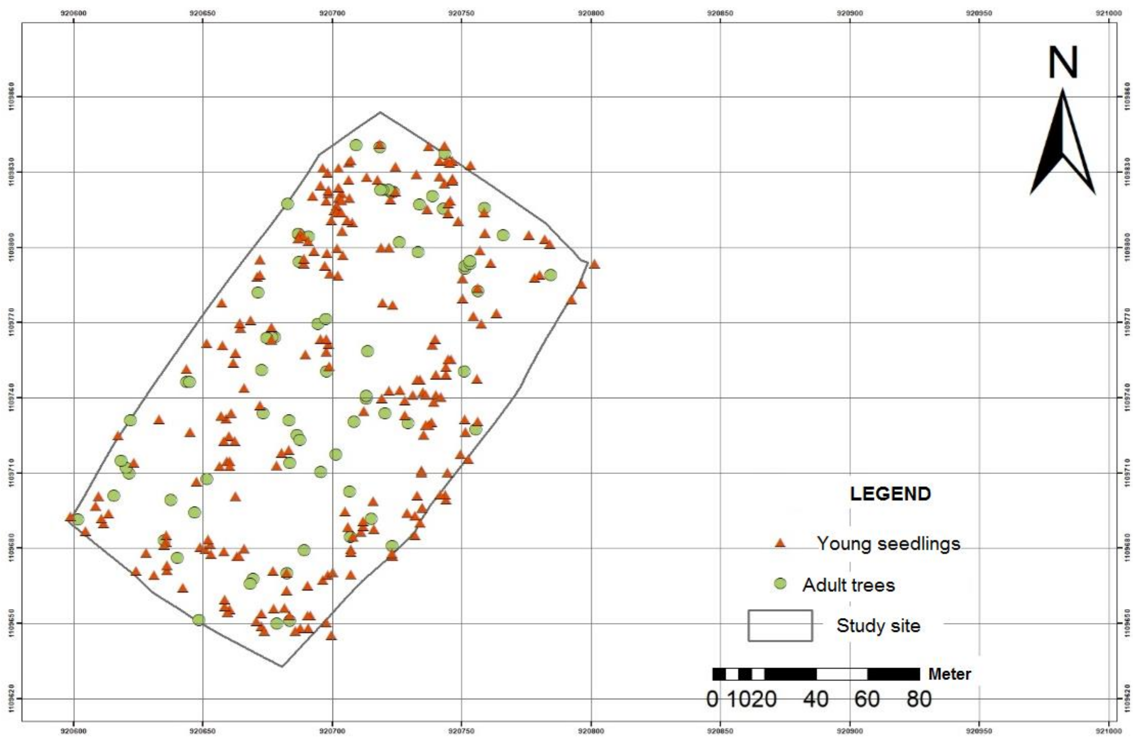

Figure 5: Spatial distribution of adult shea trees associated with shea seedlings in Ouangolodougou shea parkland

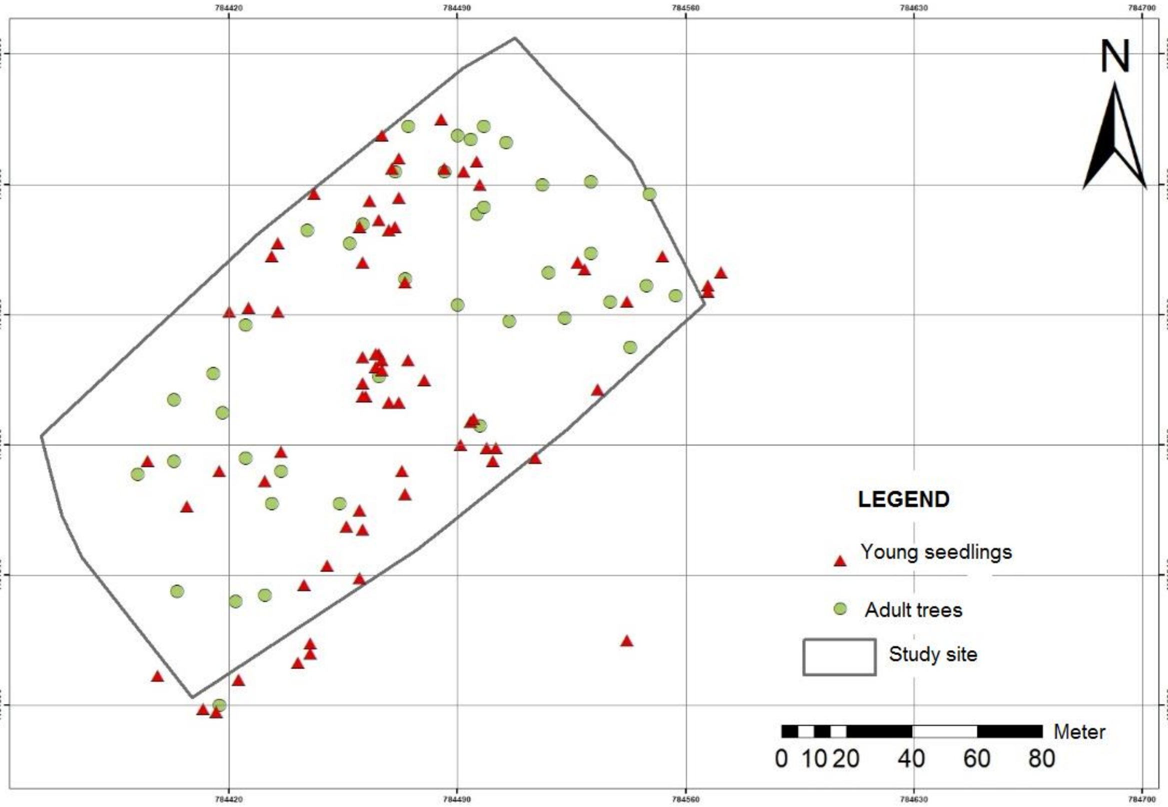

Figure 6 : Spatial distribution of adult trees associated with shea seedlings in the Tengrela shea parkland

2.4 Dendrometric characteristics of adult shea trees in the different parklands under soil types

Statistical analyzes applied to the data indicate a highly significant difference (Fcal = 13.91, P ≤ 0.01) between mean diameters in the different parklands (Table 2; Figure 7). The average height values recorded (Table 2) have a highly significant difference (Fcal = 12.46, P ≤ 0.01). Thus, the maximum height was obtained at the parkland of the Boundiali (Hm = 14.89 m), followed the one of Tengrela parkland (Hm = 14.37 m). The Ouangolodougou and Ferkéssédougou stands have a maximum height of 13.85 m and 11.57 m, respectively (Figure 8). The calculated values of the basal area estimated to 93.5 $m^2.ha^{-1}$ at Boundiali site, 17.37 $m^2.ha^{-1}$ at Ferkéssédougou site, 77.5 $m^2.ha^{-1}$ at Ouangolodougou site and 48 $m^2.ha^{-1}$ at Tengrela (Table 2). There is a highly significant difference in these estimated values (Fcal = 24.68, p ≤ 0.01).

The diameter distribution of the stems shows an "inverted J" pattern for the four diameter classes. The distribution shape coefficients of the diameter classes [100-150 [and [150-200] are 0.94 and 1.2 respectively. This reflects a high representativeness of young individuals of diameter class [100 - 200] and a small number of old individuals (Figure 9).

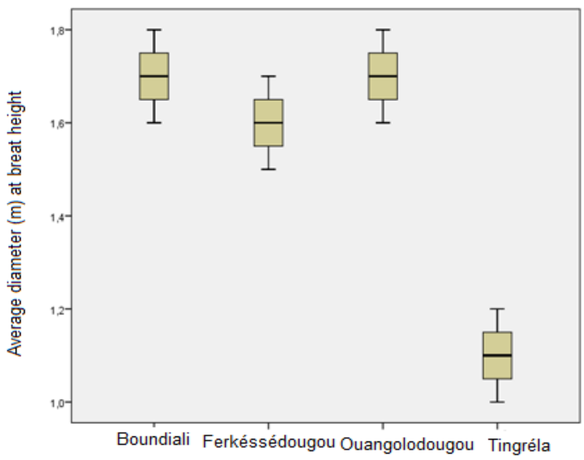

Figure 7: Average diameter (m) at breast height of different adult shea trees.

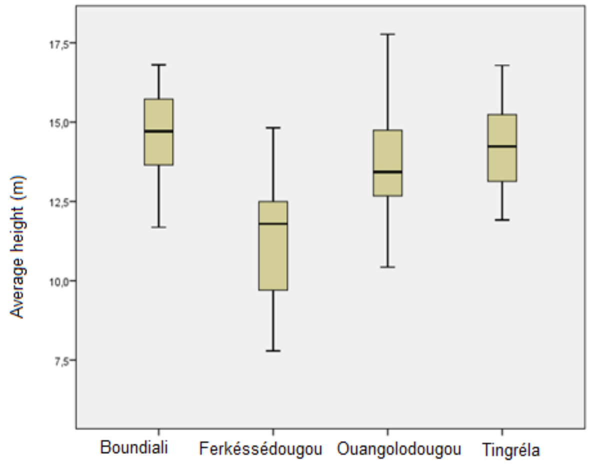

Figure 8: Average height (m) of different adult shea trees

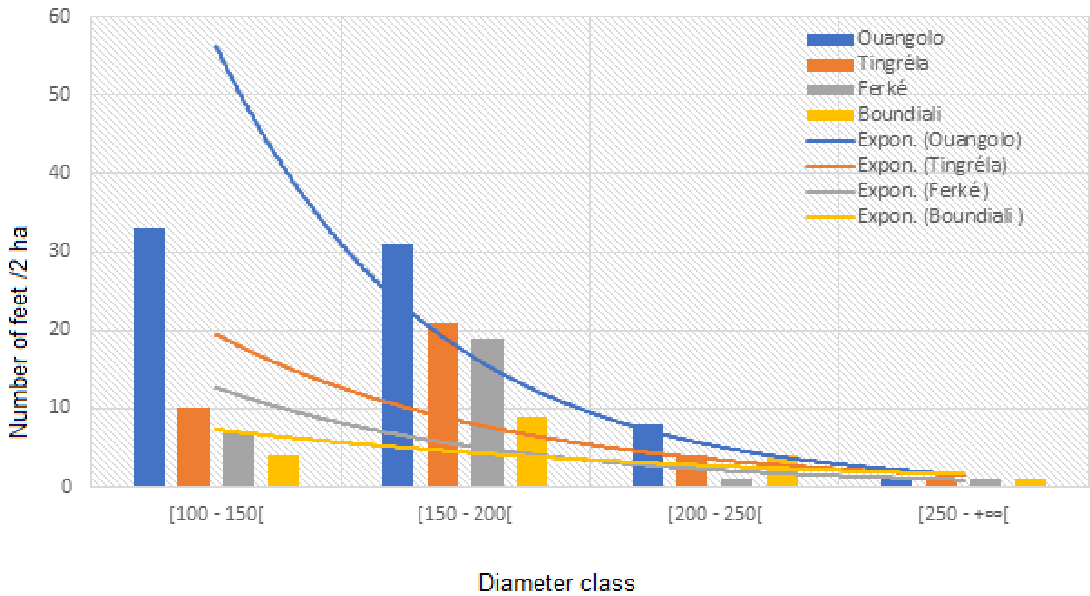

Figure 9: Distribution of stems of different adult shea trees according to diameter class

Table 2: Dendrometric characteristics of adult shea trees in parklands under soil types

Sites	Average diameter (m)	Average height (m)	Basal area (m² / ha)
Boundiali	1.83±0.51a	14.89±1.97a	93.50a
Ferkessédougou	1.00±0.53b	11.57±2.66b	17.37c
Ouangolodougou	1.55±0.53ab	13.85±2.00ab	77.50ab
Tengrela	1.71±0.51a	14.37±2.30a	48.00bc
F_{cal}	13.91**	12.46**	24.68**
P_{cal}	0.000	0.000	0.000
P_{theor}	≤ 0.01	≤ 0.01	≤ 0.01

The averages followed by the same letter, in the same column, are not significantly different at the Probability threshold <0.05, according to the TUKEY method, (F cal = Fisher calculated, Pcal = Probability calculated, P Theor = Probability Theoretical).

2.5. Biomass and carbon stock of adult stands of shea at different sites

The estimated aboveground biomass at each site is: 31.64 $t.ha^{-1}$ at Boundiali; 21.82 $t.ha^{-1}$ at Ferkéssédougou; 95.68 $t.ha^{-1}$ at Ouangolodougou and 58.33 $t.ha^{-1}$ at Tengrela site (Table 3). The Ouangolodougou site has the highest aboveground biomass in terms of the statistical analyzes applied to the data collected (Fcal = 4.71, $p \leq 0.01$). The estimation of the underground biomass gives us for: the Boundiali site 9.42 h / ha; the Ferkessedougou site 6.86 t.ha-1; the ones of Ouangolodougou and Tengrela were 29.27 $t.ha^{-1}$ and 17.52 t $t.ha^{-1}$ respectively (Table 3). The Ouangolodougou site has the highest underground biomass (Fcal = 5.84, $p \leq 0.01$). The total biomass of the shea trees in parkland assessed at the different sites is respectively 41.06 $t.ha^{-1}$ for the Boundiali site and 28.68 $t.ha^{-1}$ for the Ferkessedougou site; 124.95 $t.ha^{-1}$ at Ouangolodougou and 75 $t.ha^{-1}$ at Tengrela (Table 3). The comparative analysis of the data collected indicates that the estimated total biomasses have a highly significant difference (Fcal = 5.84, $p \leq 0.01$).

The total carbon stock was 19.3 $t.ha^{-1}$ at the Boundiali site for a sequestered CO_2 equivalent of 70.83 $t.ha^{-1}$. The shea parkland at the Ferkéssédougou site recorded 13.48 $t.ha^{-1}$ of carbon stock for $t.ha^{-1}$ in sequestered CO_2 equivalent. At the Ouangolodougou site, 58.73 $t.ha^{-1}$ of carbon stock was estimated for 215 $t.ha^{-1}$ of sequestered CO_2 equivalent. The delimited Tengrela parkland gives an estimated carbon stock of 35.65 $t.ha^{-1}$ for 130 $t.ha^{-1}$ sequestered CO_2 equivalent. The sequestered CO_2 equivalent is higher at the Ouangolodougou site, with a highly significant statistical difference (Fcal = 4.93, $p \leq 0.01$).

The total biomass and the sequestered CO_2 equivalent are higher on Ferralsols than on Cambisols, ie 200.8 $t.ha^{-1}$ compared with 69.74 $t.ha^{-1}$ for total biomass; 346.37 $t.ha^{-1}$ against 120.3 $t.ha^{-1}$ at the sequestered CO_2 equivalent.

Table 3: Biomass and carbon stock of adult shea trees in parklands stands of shea estimated per site

Sites	Aerial biomass (t/ha)	Underground biomass (t/ha)	Total biomass (t/ha)	Stock de carbone (t/ha)	Equivalent carbone (t/ha)
Boundiali	31.64 b	9.42 b	41.06 b	19.30 b	70.83 bc
Ferkéssédougou	21.82 b	6.86 b	28.68 c	13.48 c	49.47 c
Ouangolodougou	95.68 a	29.27 a	124.95 a	58.73 a	215.53 a
Tengrela	58.33 ab	17.52 a	75.85 ab	35.65 ab	130.84 b
F_{cal}	4.70**	5.84**	5.09**	5.08**	4.93**
P_{cal}	0.000	0.000	0.000	0.000	0.000
$_{Ptheo}r$	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01

The averages followed by the same letter, in the same column, are not significantly different at the Probability threshold <0.05, according to the TUKEY method, (F cal = Fisher calculated, Pcal = Probability calculated, P Theor = Probability Theoretical).

3. Discussion

Shea tree is a species that occupies an important place in the lives of rural populations in Northern Côte d'Ivoire. Income from the sale of these products contributes to the improvement of the living conditions of the populations of the rural areas (Rousseau, 2016). The spatial distribution of shea stands at the Boundiali and Ferkéssédougou sites is of a regular type. The distance between the trees is roughly constant. Individuals occupy the land approximately at the same distance from each other. However, the Ouangolodougou and Tengrela sites present an aggregative spatial distribution. Trees tend to cluster in places and the spacing between trees is relatively small (Canard and Poinsot, 2004). In general, the spatial structure of Sudanese woodland and open forest trees has an aggregative distribution (Fonton *et al.*, 2012), this is the case of Vitellaria paradoxa. These results corroborate those obtained by Djossa *et al*. (2008) who observed an aggregative distribution for *Vitellaria paradoxa* in the Pendjari Biosphere Reserve of Benin. In our study, spatial distribution is a function of soil type. An aggregative distribution is observed on Ferralsols while it is a regular distribution is observed on Cambisols. This shows that soil types influence the distribution of shea trees. The study of Obame (2015) established the respective role of soil, topographic position and topography on the distribution of certain species. In his study, these factors appear to affect the distribution of approximately 94% of the 30 species with links to environmental variables. Shea populations, irrespective of the study site, have a "reversed J" diameter distribution with decreasing individuals. This structure shows that these formations are subject to strong anthropic pressures. Indeed, this variation from one site to another is a common finding in anthropised landscapes at the scale of West African landscapes. (Folega *et al.*, 2012). These anthropogenic pressures are reinforced by the strong demographic growth coupled with poor farming practices. These different disturbances of tropical ecosystems are well known and stem from the desire to increase agricultural productivity in these landscapes. Our results are similar to those obtained by Folega *et al.* (2012) in Northern Togo, where the landscape is apparently similar to our study sites.

The morphological characterization of the soils carried out on the study sites indicates that the majority of the soils under study shea parklands, has a very low humification impregnation, sometimes shallow and battled in places. We have been given to see a strong anthropic activity on these soils. These soils have characteristics of degraded soils. These results are consistent with those of N'Guessan *et al.* (2015) which indicate that overgrazing and the continuous cultivation of soils in Northern Côte d'Ivoire contribute significantly to reduce the vegetation cover and the organic matter content thus favoring soil compaction. Thus, the consequence of low organic matter content in the long term is not only detrimental to soil fertility but acts on the equivalent rate of sequestered CO_2. The aim of this work is to estimate the CO_2 equivalent sequestered in the different sites. However, this estimate is based on an assessment of the number of trees per hectare, the characteristics of woody biomass (density and basal area) and the sequestered carbon stock. The Ouangolodougou site recorded more seedlings (233 plants) compared to the other sites: Boundiali (165 plants), Ferkessédougou (82 plants) and Tingrela (71 plants). At the level of mature trees, of the 2 ha surveyed, the Ouangolodougou site has more (75 trees) compared to the other sites: Tingrela (40 trees), Ferkéssédougou (30 trees) and Boundiali (18 trees). On all sites, the total biomass of the shea population evaluated is 41.06 t.ha-1 for the Boundiali site and 28.68 t.ha-1 for the Ferkéssédougou site; 124.95 t.ha^{-1} at the Ouangolodougou site and 75 t.ha^{-1} at Tengrela. The total carbon stock was estimated at 19.3 t.ha^{-1} at the Boundiali site for a sequestered CO2 equivalent of 70.83 t.ha^{-1}. The Shea stand at the Ferkéssédougou site recorded 13.48 t.ha^{-1} of carbon stock for 49.47 t.ha^{-1} in sequestered CO_2 equivalent.

At the Ouangolodougou site, 58.73 t.ha^{-1} of carbon stock was estimated for 215 t.ha^{-1} equivalent of sequestered CO_2. The delimited Tingrela stand gives an estimated carbon stock of 35.65 t.ha^{-1} for 130 t.ha^{-1} equivalent of sequestered CO_2. The CO_2 sequestered equivalent is higher at the Ouangolodougou site. Comparing our results to those obtained by Kombaté *et al*. (2019), the CO_2 equivalent sequestered by shea parklands is higher. In fact, carbon storage and CO_2 are proportional to the amount of tree biomass and several factors can influence its storage. Carbon fluxes have a high spatial variability, mainly related to the variability of pedo-climatic conditions, management methods, vegetation types and forms of ecosystem use (Tsoumou *et al.*, 2016**)**. Various factors influence the variability of tree biomass. In tropical rainforest, the biomass of a tree is mainly influenced by trunk diameter, crown diameter and wood density. The capacity of a forest or plant stand to store carbon depends mainly on the species that make it up and on the diameter classes of the trees; environmental factors and tree factors (GIEC, 2006). Environmental factors that may influence carbon capture include the effect of topography, plant distribution, soils, disturbance, climate, insect and disease tolerance, age, the structure and type of land use. Some of these factors are specific to trees that may affect carbon storage and even the growth strategy (Kombaté *et al*., 2019).

Conclusion

Shea parklands, regardless of the study site, have a diametric distribution in "inverted J" with decreasing individuals. This structure shows that these formations are subject to strong anthropic pressures. The characteristics of the shea parklands studied show that the diametric structure of the identified trees remains dominated by the stems of small diameter classes, capable of ensuring its reconstitution if appropriate measures of defenses are undertaken. The spatial distribution of shea trees in parklands at the Boundiali and Ferkéssédougou sites is of a regular type. However, the Ouangolodougou and Tengrela sites present an aggregative spatial distribution. The spatial distribution of trees depends on the type of soil. Biomass and carbon stocks are essential for the implementation of climate change mitigation strategies, including the mechanism for reducing emissions from deforestation and degradation. Our study sites are mostly shrub savannas. Comparing our results with those obtained by some authors, the CO_2 equivalent sequestered by shea trees in parklands seems high. Soil types strongly influenced the CO_2 equivalent sequestered in these shea parklands. It is therefore necessary to promote agroforestry practice in Northern Côte d'Ivoire through the domestication of shea tree, in order to maintain carbon sinks and limit greenhouse gas emissions in the atmosphere, especially in the North of Côte d'Ivoire. This will certainly facilitate Côte d'Ivoire's access to the carbon market and the possibility of payments to farmers for their contribution to mitigating climate change.

Competing interests

The authors declare that they have no competing interests

Acknowledgements

The authors thanks to the *Fond Compétitif pour l'Innovation Agricole* (FCIAD) of Côte d'Ivoire, which fully funded this work through the fellowship agreement 1674/FIRCA/UPGC/FADCI-FCIAD/2017.

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