

Full Length Research Paper

Comparative study of the carbon stock of a cashew tree plantation (*Anacardium occidentale* L.) and secondary forest in Casamance, Senegal

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Abstract. The role of trees in carbon sequestration is of major importance in this global context of global warming. In view of the extent of degradation of forest resources in Casamance, it is necessary to evaluate the carbon stock potential of the secondary forests and cashew tree plantation, which are the main forest formations in this part of Senegal. For this purpose, an allometric equation was used to estimate the dry biomass. This assessment was made based on a floristic inventory carried out using 150 plots dimension 20 m x 20 m and the secondary forest 96 plots dimension 50 m x 50 m. The results show that the species richness in the secondary forest is 45 species with a density of 696 individuals / ha. In the cashew tree park, it is 8 species with a density of 205 individuals / ha. A comparison of carbon stock shows that the secondary forest has a potential of 58.274 t C/ha and 109.398 t C/ha for cashew tree plantation with a significant difference ($p = 3.09e^{-12}$). The CO₂ equivalent varies respectively from 213.69 t/ha for the secondary forest and 401.14 t/ha for the cashew tree plantation ($p = 1.14e^{-12}$). This study shows that cashew tree plantation have a higher carbon sequestration potential than secondary forest and contribute significantly to the reduction of CO₂ emissions to the atmosphere.

Keywords: Carbone sequestration; Secondary forest; Cashew Tree Park; Global warming

1. INTRODUCTION

The increase in carbon emissions is one of the main concerns in the context of climate change (Yenonfan et al., 2020). According to several studies, it is shown that forests constitute a carbon reservoir to store CO₂ located in the atmosphere (Alamgir et al., 2008).

Currently, studies on agricultural production systems and climate change are mainly limited to the quantification of greenhouse gas emissions (CO₂, CH₄, N₂O) due to nitrogen fertilization, decomposition of organic matter, animal excreta, etc. (Dixon *et al.*, 1994). Carbon sequestration projects eligible for the eco-friendly development mechanism are currently tree plantations and natural forest regeneration.

However, there is a growing interest in agroforestry activities (Valentini, 2007). Indeed, forest vegetation and soils store about 60% of total terrestrial carbon (Winjum et al., 1998).

The importance of the tree has received particular attention from several researchers due to its potential in climate change mitigation (Schroeder et al., 1993; Mitchell Aide et al., 2000; Oelbermann et al., 2004). It is reported that the carbon sequestration capacity is higher in agroforestry and forestry systems than in conventional agricultural systems, since the aboveground biomass present is more important (Dixon, 1994; Palm *et al.*, 2000; Albrecht and Kandji, 2003).

However, natural forest ecosystems in West Africa, and more particularly in Senegal, are being subjected to a series of transformations to make way for agroforests (Yabi et al., 2013), classic cashew tree plantations (*Anacardium occidentale* L.) (Ndiaye et al., 2020), and crop fields with modified floristic composition (Yaméogo et al., 2005; Meunier et al., 2014).

As in several countries, in Senegal and particularly in Casamance, natural forest ecosystems are increasingly giving way to cashew tree agrosystems (Ndiaye, 2020). Indeed, according to Samb et al. (2018), the surface area of cashew tree plantation in Senegal increased from 910.55 km² to 1908.5 km² between 1986 and 2017.

As a result, plateau areas are the most prone to the expansion of cashew tree plantation. Thus, more than 80% of the plateau lands are occupied by cashew trees (PADEC, 2016). In this context of climate change, these cashew agroforests could contribute to climate change mitigation through the absorption of CO₂ emissions. The objective of this study is to evaluate the potential of carbon sequestration in cashew tree parks compared to a secondary forest in Casamance.

2. MATERIALS AND METHODS

2.1. Study area

The inventories were carried out in six (07) sites including 05 in the department of Goudomp, 01 in the department of Ziguinchor and 01 in the department of Oussouye. Casamance covers an area of 28,350 Km² or 1/7 of the area of Senegal. It is bordered from East to West by a 300 km long river that gives its name to the region (Sané et al, 2010). These are the regions of Ziguinchor, Sédhiou, and Kolda, respectively in Lower, Middle, and Upper Casamance (Figure 1).

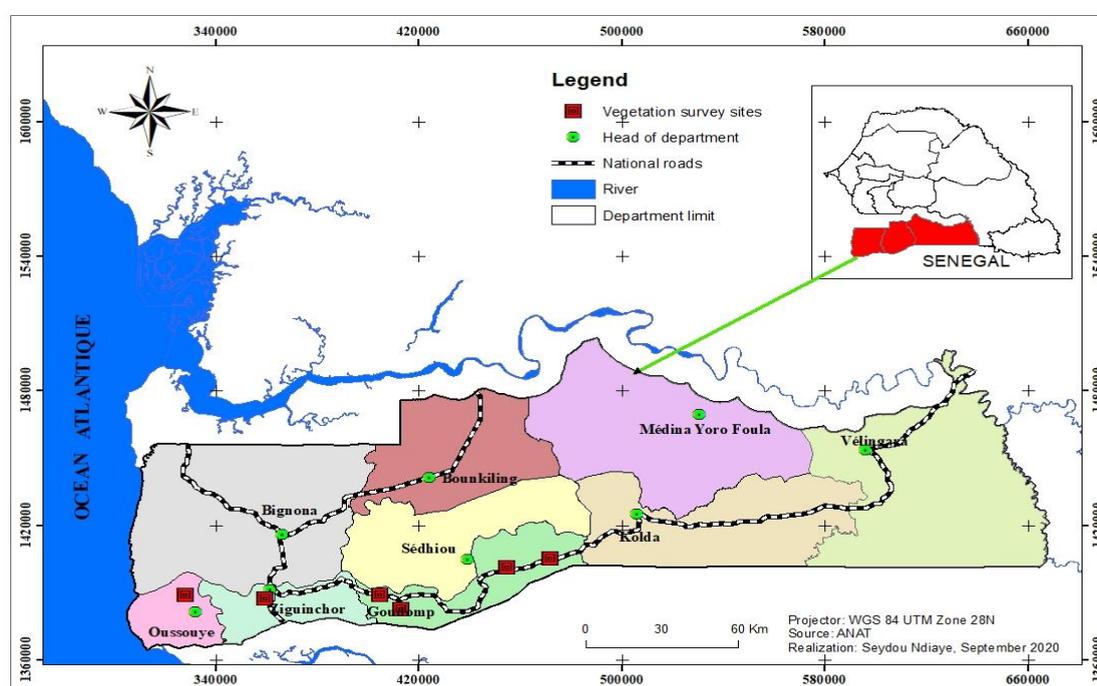


Figure 1: Location of inventoried sites

2.2. Sampling

2.2.1. Cashew tree plantations Inventory

Cashew tree sampling is carried out at 05 sites, 4 of which are in the Goudomp department and 01 in the Ziguinchor department. The intensity of cashew nut production in the different localities guided the choice of sites. A total of 16 plantations were inventoried. Over an area of 50 ha, divided into 96 plots of 50 m x 50 m with 6 plots/planting.

2.2.2. Secondary forest inventory

The opening of the layons was adopted to facilitate the inventory given that the forest is very dense and almost impenetrable. For this purpose, 6 layons equidistant of 100 m were cleared and on each layon, square plots of 20m x 20m side, equidistant of 10 m were installed. A total of 150 plots were created to cover the entire area to be inventoried, which corresponds to an area of 6 ha. The sampling rate is 18.75%.

Each survey area is pre-defined (by method 3-4-5) with a 50m long tape measure, delimited by 8 stakes and located using a GPS (Global Positioning System) device. In each vegetation survey, an inventory of woody species with a diameter at chest height higher than 10 cm was carried out. Measurements of

dendrometric parameters included the height of the individuals and the diameter of the trunk at 0.3 m from the ground.

2.3. Carbon estimation methods

To measure the amount of carbon sequestered in an ecosystem, scientists generally assess the biomass present in the plots, since plants accumulate atmospheric CO₂ in their cellular components (Tufekcioglu *et al.*, 2003; Sharrow and Ismail, 2004). GIEC (2001) defines biomass as the "total mass of living organisms within a perimeter or volume". Therefore, it is expressed in kilograms (on a dry weight basis). To obtain the quantity of total carbon sequestered in a plot, the biomass is multiplied by the carbon content of the plants. It has been reported that the carbon contained in the dry biomass of a tree is 50% (Malhi *et al.*, 2004). In this study, the dry biomass present in the aboveground and below-ground components is evaluated (Table 1).

Table 1: Biomass estimation models

Allometric model	Formulas
Cairns <i>et al.</i> (1997)	<ul style="list-style-type: none"> ▪ Aerial biomass (AB) = (-0.463*D) + (0.356*D²) + (0.008*D³) ▪ Root biomass (RB) = Exp (-1.0587+ (0.8836*ln (RB))) ▪ With D: diameter chest height and total biomass = AB +RB

The atomic molar mass of carbon is 12 and the atomic weight of oxygen is 16. So the atomic weight of the CO₂ molecule is C+2xO: 12+ 2x16= 44. The ratio of the atomic weight of CO₂ to that of carbon is 3.667. To determine the quantity of atmospheric CO₂ sequestered by the tree, the carbon stock in the tree is multiplied by 3.667 (Cienciala *et al.*, 2005).

2.4. Data processing

Diversity indices were used to study the diversity of the woody tree. The Shannon index (H₀) is used to calculate the level of species diversity in a given environment. It takes into account not only the number of species, but also the distribution of individuals within these species. It is often between 0 and 4.5, rarely higher. It is calculated using the following equation:

$$H' = -\sum_{i=1}^S Fi \log(2)Fi \text{ avec } Fi = \text{Frequency of species } i \text{ (Legendre et Legendre, 1984).}$$

The value of the index varies according to the number of species present and their relative proportions. This makes its use less exhaustive for the comparison of two environments with very different specific richness. Thus, Evenness index (E) becomes more interesting for comparing different environments (Devineau *et al.*, 1984). The value of the index varies from 0 to 1; a high value of this index (i.e. close to 1) indicates that the stand is homogeneous, or that individuals are equitably distributed among the different species. On the other hand, when the index value is low (i.e. close to 0), the stand is dominated by one or a few species.

Evenness expresses the distribution of species within the association. It varies between 0 and 1, is without units, and corresponds to the ratio of Shannon index (H₀) and maximum value of Shannon index (H' max):

Evenness is represented as follows:

$$E = \frac{H'}{H'_{\max}} \text{ with } H' = \text{Shannon index; } H'_{\max} = \log_2 S, S \text{ is the total specific richness.}$$

The Jaccard similarity index allows a comparison between two sites, as it assesses the similarity between two surveys by relating the species common to both surveys to those specific to each survey. Jaccard's similarity index is represented as follows:

$J = \frac{a}{a+b+c}$ where a is the number of species present in both samples (joint occurrences), b is the number of species present in sample one, and c is the number of species present in sample two.

The density of a species is the number of feet belonging to the species per unit area. It is expressed in number of individuals per hectare (n.ha-1.).

Diameter classes and amplitudes and were defined using the formula of Sturges (1926):

Number of classes = $1 + 3,3 \log_2 N$ where N is the sample size

The amplitude (P) is obtained by: $P = \frac{i \text{ Max} - i \text{ Min}}{C}$ where i represents the sample values.

3. RESULTS

3.1. Specific richness and density

The inventory carried out in the natural forest allowed to identify 45 species with different proportions in terms of density. The average density is 694 individuals/ha. The dominant species are: *Detarium guineensis* Gmel. (122 individuals/ha) followed by *Trichilia prieureana* A. Juss. (84 individuals/ha), *Eleais guineensis* Jacq. (72 individuals/ha) and *Fagara zantoxylodes* Lam. (55 individuals/ha). In the cashew tree plantation, 8 species were inventoried with an average density of 8 species/ha. Cashew tree plantation density is 180 individuals/ha (Table 2).

Table 2: Characteristics of the two types of ecosystems

Secondary forest	Abundance (Number of individuals)	Cashew tree plantation from 18 to 25 years old	Abundance (Number of individuals)
Floristic composition		Floristic composition	
<i>Adansonia digitata</i> L.	22	<i>Anacardium occidentale</i> L.	180
<i>Albizia zygia</i> (DC.) J.F. Macbr.	6	<i>Eleais guineensis</i> Jacq.	3
<i>Azelia africana</i> Smith.	13	<i>Tectona grandis</i>	14
<i>Allophyllus africanus</i> P. Beauv.	53	<i>Mangifera indica</i> L.	2
<i>Alchornea cordifolia</i> (Schumach. & Thonn.) Müll. Arg.	20	<i>Parkia biglobosa</i> (Jacq.) R. Br.	3
<i>Anacardium occidentale</i> L.	12	<i>Ficus copensis</i>	1
<i>Anthocleista procera</i> Lepr.	12	<i>Adansonia digitata</i> L.	1
<i>Annona senegalensis</i> Pers.	57	<i>Ceiba pentandra</i> (L.) Gaertn	1
<i>Anthostema senegalensis</i> Juss., W.	103		
<i>Antiaris africana</i> Engl.	4		
<i>Borassus akeassii</i> Bayton, Ouédraogo & Guinko	26		
<i>Ceiba pentandra</i> (L.) Gaertn	17		
<i>Carapa procera</i> Dc	2		
<i>Citrus medica</i> L.	1		
<i>Combretum micrantum</i> G. Don	2		
<i>Dalbergia melanoxylon</i> Guill. & Perr.	3		
<i>Dialium guineensis</i> Willd.	26		
<i>Detarium guineensis</i> Gmel.	734		
<i>Dichrostachys glomerata</i> (Forssk.) Chiov	179		
<i>Eleais guineensis</i> Jacq.	434		
<i>Fagara rubescens</i> (Planch. ex Hook.f.)	5		
<i>Fagara zantoxylodes</i> Lam.	331		
<i>Faidherbia albida</i> (Del.) Chev.	29		
<i>Ficus sycomorus</i> ssp. <i>gnaphalocarpa</i> (Miq.) C.C. Berg	73		
<i>Ficus thonningii</i> Blume.	12		
<i>Ficus vogelii</i> (Miq.) Miq.	3		
<i>Chlorophora regia</i> A. Chev.	1		
<i>Khaya senegalensis</i> (Desr.) A. Juss.	4		

<i>Kigelia africana</i> (Lam.) Benth.		95		
<i>Landolphia heudelotii</i> A. DC.		201		
<i>Lannea acida</i> A. Rich.		35		
<i>Malacantha alnifolia</i> (Bak.) Pierre		168		
<i>Mangifera indica</i> L.		293		
<i>Nauclea latifolia</i> Sm.		11		
<i>Parinari excelsa</i> Sabine.		8		
<i>Parinari macrophylla</i> Sabine		175		
<i>Parkia biglobosa</i> (Jacq.) R. Br.		92		
<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.		27		
<i>Sabicea venosa</i> Benth.		273		
<i>Saba senegalensis</i> (A. DC.) Pichon		19		
<i>Spondias monbin</i> L.		2		
<i>Trichilia prieureana</i> A. Juss.		509		
<i>Terminalia macroptera</i> Guill. & Perr.		21		
<i>Uvaria chamae</i> P. Beauv.		28		
<i>Vitex doniana</i> Sweet		1		
Total	45 species	696 individuals / ha	08 species	205 individuals / ha

3.2. Relationship between density and basal area in the two types of ecosystems

The carbon sequestration potential depends on the density and diameter of the trees. It is important to know the structural parameters of both types of formations. Thus, in cashew tree plantation, since the individuals consist of large trees with high density (205 individuals / ha), the density is highly correlated to the basal area ($R^2 = 0.8859$). This reflects a good distribution of the aerial cover of the trees (Figure 2A). As for secondary forests, despite the high density noted (694 trees/ha), the density is not highly correlated ($R^2 = 0.325$) with the basal area because of the predominance of young trees (Figure 2B).

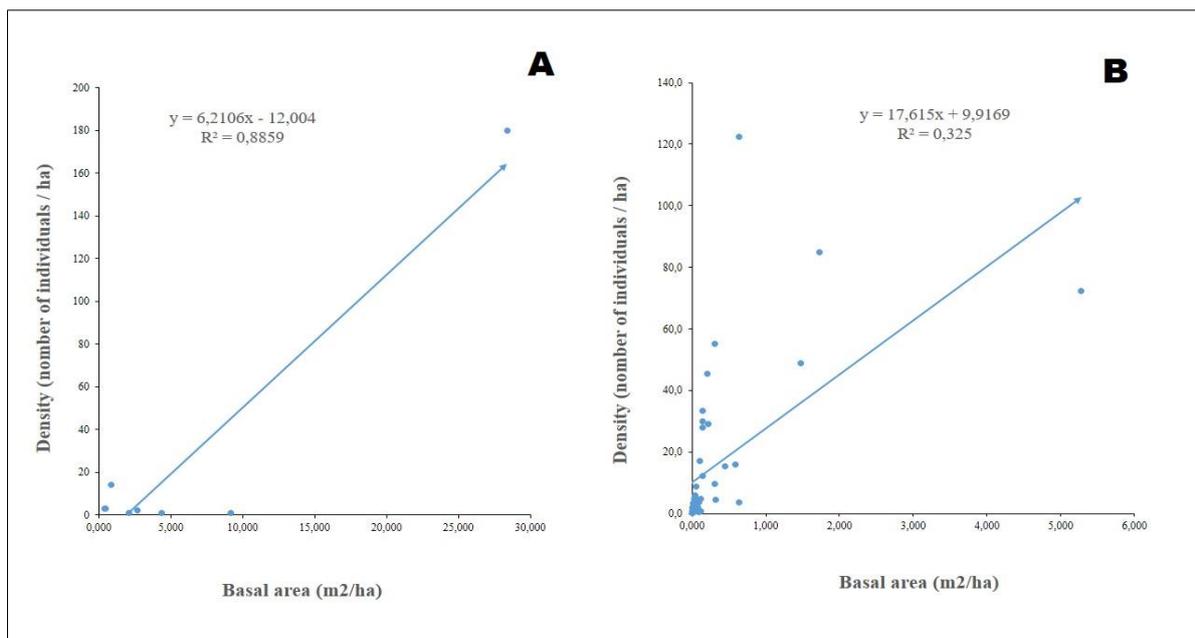


Figure 2: Density regression models as a function of basal area: **A** = cashew tree plantation and **B** = secondary forest.

3.3. Shannon index and Evenness

L'indice de Shannon qui permet d'apprécier la distribution des individus suivant les espèces montre que les individus sont équitablement répartis par espèces dans les forêts secondaires ($H' = 4,13$ bits). Dans les parcs à anacardier, c'est plutôt le contraire qui a été noté où l'anacardier est l'espèce dominante ($H' = 0,8$ bit). Le test de Student Newman Keuls montre une différence significative de la distribution des individus par espèces entre les ces types de formations végétales ($p = 5,86e^{-15}$). L'indice d'équitabilité de Piellou plus exhaustif pour la comparaison de deux milieux montre également que les forêts secondaires de la Casamance sont homogènes et que les parcs à anacardier sont dominés par une seule espèce (Tableau 3).

Shannon's index, which allows to appreciate the distribution of individuals according to species, shows that individuals are equitably distributed by species in secondary forests ($H' = 4.13$ bits). In the cashew tree plantation, it is rather the opposite which was noted where the cashew tree is the dominant species ($H' = 0.8$ bit). The Student Newman Keuls test shows a significant difference in the distribution of individuals by species between these types of formations ($p = 5.86e^{-15}$). The more exhaustive Evenness index for the comparison of two environments also shows that the secondary forests of Casamance are homogenous and that cashew tree plantation are dominated by a single species (Table 3).

Table 3: Diversity index

Variables	Shannon index (H')	Evenness (E)
Secondary forest	4.13 bits (a)	0.75 (a)
Cashew tree plantation	0.8 bit (b)	0.27 (b)
Pr (>F)	5.86e ⁻¹⁵ ***	2e ⁻¹⁶ ***

*Signif. codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*
The letter (a-b) represents the significant differences between the indices of the two types of vegetation formations.

3.4. Jaccard similarity index

This index measures the proportion of common species between the two environments. It shows that the similarity of the environments in terms of species is very low (13%). The diversity is very different in the two plant formations (Table 4).

Table 4: Jaccard similarity index

	Secondary forest	Cashew tree plantation
Secondary forest	1	
Cashew tree plantation	0.13	1

3.5. Carbon stock and economic equivalent to the REDD+ market

The carbon stock estimate shows that it is 58.274 t C/ha in secondary forests compared to 109.398 t C/ha in cashew tree plantation. However, the Newman Keuls test at the 5% threshold shows a significant difference in carbon stock between these two ecosystems formations ($p = 3.09e^{-12}$). The CO₂ equivalent is 213.69 t /ha for secondary forests and 401.14 t/ha for cashew tree plantation with a significant difference ($p = 1.14e^{-12}$). This gives an economic value of 1,946,224.4 FCFA for secondary forests and 3,653,667.3 FCFA for cashew tree plantation (Table 5).

Table 5: Estimation of biomass, carbon stock and equivalent economic value / ha

Variables	Secondary forest	Cashew tree plantation	Student Newman Keuls Test at the 5% threshold
Aerial Biomass (BA)	99.275 t/ha	198.343 t/ha	Pr (>F) = 0.0019 **
Root Biomass (BR)	17.273 t/ha	20.453 t/ha	Pr (>F) = 0.000568 ***
Total Biomass (BT)	116.548 t/ha	218.796 t/ha	Pr (>F) = 2e ⁻¹⁶ ***
Sequestered carbon stock	58.274 t C/ha	109.398 t C/ha	Pr (>F) = 3.09e ⁻¹² ***
CO ₂ equivalent	213.69 t/ha	401.14 t/ha	Pr (>F) = 1.14e ⁻¹² ***
REDD+ carbon price (14 Euro/T)	2991.66	5616.27	---

REDD+ carbon price (FCFA)	1 946 224.4	3 653 667.3	---
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*Signif. codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

3.1. Distribution of CO₂ stock and basal area according to diameter classes

The CO₂ stock and the basal area evolve proportionally for each of the two types of formations according to the different diameter classes. The highest values of sequestered CO₂ correspond to the highest values of the basal area. For cashew tree plantation (Figure 3), the high value of the CO₂ stock starts from the diameter (≥ 95 cm).

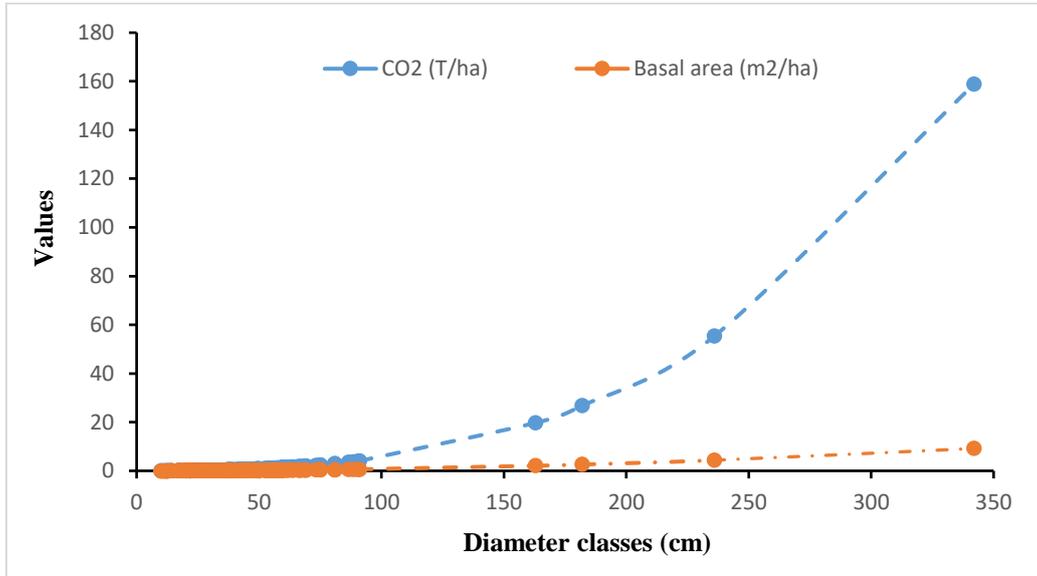


Figure 3: Distribution of CO₂ equivalent and basal area by diameter classes in cashew tree plantation

In the secondary forest (Figure 4), this value starts from 12 cm. In general, the high density has a negative impact on the CO₂ stock. For this implies a decrease in the size of tree diameters.

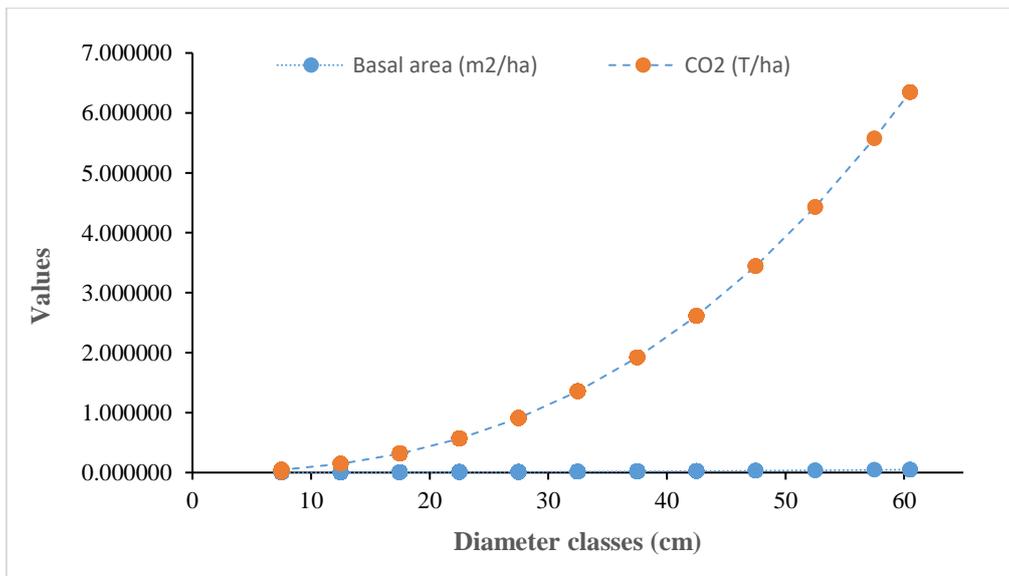


Figure 4: Distribution of CO₂ equivalent and basal area by diameter classes in a secondary forest

4. DISCUSSION

The diversity within the two types of ecosystems shows that the establishment of cashew tree plantation leads to selective cutting of more than 37 species in secondary forests in Casamance. This low diversity noted in cashew tree plantation was reported by Ndiaye et al. (2017) who reported a diversity of 5 species/plantation at the level of the

former rural community of Djibanar in Senegal. Other authors showed that agroforestry systems offer higher diversity, which varies according to silvicultural techniques and localities (Sonwa et al., 2001; 2007; Zapfack et al., 2002). According to Manfo et al. (2015) a cocoa-based agroforest can conserve up to 47 species depending on the use systems in the plots. The absence of regeneration in the cashew tree plantation is explained by the intensity of the work during the plantation maintenance prior to nut collection operations. Indeed, just before the nut harvest, the producers clean the cashew nut plantations to facilitate the collection. This does not encourage the development of young plants (Ndiaye, 2020). The morphological variability of the different individuals shows that in the secondary forests of Casamance, individuals of medium diameters are very present contrary to cashew tree plantation which are mostly composed of large diameters.

However, given the morphological and physiological variability of woody species, Montagnini and Nair (2004) reports that the amount of carbon sequestered is dependent on tree species, geographical regions (climate, soil), planting densities and management of the system. Thus, the highest densities were noted at the level of secondary forests (696 individuals / ha) and 205 individuals / ha for cashew tree plantation.

The carbon stock in the secondary forests and cashew tree plantation of Casamance are estimated at 58.274 t C/ha and 109.398 t C/ha respectively. For the secondary forests, this value is almost equal to that of France (59 t C/ha), the Netherlands and Belgium (60.8 t C/ha) (Pignard et al., 2000; Lebègue et al., 2004). Compared to cashew tree plantation, they have a higher carbon stock potential than forests in Germany, which is 100 t C/ha (Baritz, Strich, 2000).

Even if the soil component was not taken into account in this study, the values obtained in cashew tree plantation are much higher than those obtained in Néré and Karité plantation in Benin. The carbon stock in these parks varies 32.62 ± 5.91 t C/ha. In Côte d'Ivoire, Gueulou et al. (2020) obtained a mean carbon stock value of 22.21 t C/ha at the Lamto Scientific Reserve.

According to Albrecht and Kandji (2003), the carbon stock capacity of an agroforestry system varies between 12 and 228 t C/ha with an average value of 95 t C/ha. This defined interval confirms the results obtained in this study with regard to cashew tree plantation.

5. CONCLUSION

This study showed that cashew tree plantation, beyond their economic and social contribution to the health of rural populations, can play a major role in carbon stock thanks to the high potential of cashew tree plantation in terms of atmospheric carbon storage. Thus, it is necessary to apply rigorous management in these agro-systems so that they can fully play their role in mitigating CO₂ emissions into the atmosphere.

Conflict of Interest: authors declare that there is no conflict of interest.

REFERENCES

- Alamgi M. and Al-Amin M. (2008). Allometric models to estimate biomass organic carbon stock in forest vegetation. *Journal of Forestry Research* 19, 101–106.
- Albrecht, A. et Kandji, S.T. (2003). Carbon sequestration in tropical agroforestry systems. *Agriculture, Ecosystems and Environment*, 99: 15-27.
- Baritz R., Strich S. (2000). Forests and the National Greenhouse Gas Inventory of Germany. *Biotechnol. Agron. Soc. Environ.* 4 (4), p. 267–271.
- Cairns, M.A., S. Brown, E.H. Helmer, G.A. Baumgardner. (1997). Root biomass allocation in the world's upland forests. *Oecologia*.111, 1-11.
- Cienciala E., Apltauer J., Cerny M., and Exnerova Z. (2005). Biomass functions applicable for European beech, *Journal of Forest Science* 51: 147–154.
- Devineau J., Lecordier C. & Vattoux R. (1984). Evolution de la diversité spécifique du peuplement ligneux dans une succession préforestière de colonisation d'une savane protégée des feux (Lamto, Côte d'Ivoire). *Conservatoire et jardin botanique Genève*, 39(1), 103-133
- Dixon, R.K., Brown, S., Houghton, R.A., Solomon, A.M., Trexler, M.C. and Wisniewski, J. (1994). Carbon pools and flux of global forest ecosystems. *Science* 263, 185–190.
- GIEC. (2001). Bilan 2001 des changements climatiques : *mesures d'atténuation*. Rapport du groupe de travail III du GIEC. Cambridge University Press, Cambridge, UK, 93 p.

- Gueulou N, Douffi K G-C, Yenilougo S, Kone M, and Bakayoko A. (2020). Evaluation de la couverture forestière et du stock de carbone forestier de la réserve scientifique de Lamto (Côte d'Ivoire). *International Journal of Innovation and Applied Studies*. Vol. 28 N°3, pp. 682-689
- Lebègue C., Laitat É., Perrin D., Pissart G. (2004). Mise en œuvre de carottages de sol et de minirhizotrons pour l'étude à long terme de la réponse des fines racines d'épicéa (*Picea abies* (L.) Karst.) à l'augmentation de la concentration en CO₂ dans l'atmosphère. *Biotechnol Agron. Soc. Environ.* 8 (1), p. 41–53
- Legendre, L. & Legendre. P. (1984). La structure des données écologiques. 2^{ème} Cd. Tome 2. Masson. Paris et les Presses de L'Université du Québec. 260p.
- Malhi Y, Baker TR, Phillips OL, Almeida S, Alvarez E, Arroyo L, Chave J, Czimczik CI, Di Fiore A, Higuchi N, Killeen TJ, Laurance SG, Laurance WF, Lewis SL, Montoya LMM, Monteagudo A, Neill DA, Nunez Vargas P, Patin˜ o S, Pitman NCA, Quesada CA, Silva JNM, Lezama AT, Vasques Martinez R, Terborgh J, Vinceti B, Lloyd J. (2004). The above-ground coarse wood productivity of 104 Neotropical forest plots. *Glob Change Biol* 10:563–591
- Manfo, D. A., Tchindjang, M., Youta, H. J. (2015). Systèmes agroforestiers et conservation de la biodiversité dans un milieu fortement anthropisé : le cas d'Obala. *Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo*, 5, 22-34
- Meunier, Q., Boldrini S., Moumbogou C., Morin A., Ibinga S., Vermeulen C. (2014). Place de l'agriculture itinérante familiale dans la foresterie communautaire au Gabon. *Bois et Forêts des Tropiques*, 319 (1) : 65-69.
- Mitchell Aide, T., Zimmerman, J.K., Pascarella, J.B., Rivera, L. et Marcano-Vegas, H. (2000). Forest regeneration in chronosequence of tropical abandoned pastures: implications for restoration ecology. *Restoration Ecology*. 8(4): 328-338.
- Montagnini, F. et Nair, P.K.R. (2004). Carbon sequestration: An underexploited environmental benefit of agroforestry systems. *Agroforestry Systems*. 61: 281-295.
- Ndiaye S, Charahabil M M, Diatta M, Aidara Fall C A L. (2020). Effet de l'anacardier (*Anacardium occidentale* L.) sur les propriétés physicochimiques des sols (Casamance / Sénégal). *American Journal of Innovative Research and Applied Sciences*. 10 (2): 44-54
- Ndiaye S, Charahabil M M, Ndiaye O, Diatta M. (2017). Influence de la flore ligneuse associée dans la production des parcs à *Anacardium occidentale* L. dans la communauté rurale de Djibanar (Casamance/Sénégal). *Int. J. Biol. Chem. Sci.* 11(2): 585-596
- Ndiaye S. (2020). Caractérisation agroécologique et socioéconomique des systèmes de production des parcs à anacardier En Casamance (Sénégal). Thèse de doctorat, ED-STI, Université Assane Seck de Ziguinchor. 158p
- Oelbermann, M., Voroney, R.P. et Gordon, A.M. (2004). Carbon sequestration in tropical and temperate agroforestry systems: a review with examples from Costa Rica and southern Canada. *Agriculture, Ecosystems & Environment*. 104: 359-377.
- PADEC. (2016). Programme de l'Appui au Développement Economique de la Casamance. Enquête sur le sous-secteur de l'anacarde au Sénégal. Résumé global. 23p
- Palm, C.A., Woomeer, P.L., Alegre, J., Arevalo, L., Castilla, C., Cordeiro, D.G., Feigl, B., Hairiah, K., Kotto-Same, J., Mendes, A., Moukam, A., Murdiyarsa, D., Njomgang, R., Parton, W.J., Rice, A., Rodrigues, V., Sitompul, S.M. et Van Noordwijk, M. (2000). Carbon sequestration and trace gas emissions in slash-and-burn and alternative landuses in the humid tropics. Final Report, Alternatives to Slash and Burn (ABS). Climate Change Working Group, Phase II. ICRAF, Nairobi, Kenya. 29 p.
- Pignard G., Dupouey JL., Arrouays D., Loustau D. (2000). Carbon stocks estimates for French forests. *Biotechnol. Agron. Soc. Environ.* 4 (4), p. 285–289.
- Samb C.O, Faye E, Dieng M, Sanogo D, Samba NSA et Koita B. (2018). Dynamique spatio-temporelle des plantations d'anacardier (*Anacardium occidentale* L.) dans deux zones agro-écologiques du Sénégal. *Afrique SCIENCE* 14(3) (2018) 365 – 377.
- Sané T., Benga A. et Sall O, 2010. La Casamance face aux changements climatiques : enjeux et perspectives. 23^{ème} Colloque de l'Association Internationale de Climatologie, Rennes 2010. 559-564
- Schroeder, P.E., Dixon, R.K. et Winjum, J.K. (1993). Ordenación forestal y agrosilvicultura para reducir el dióxido de carbono atmosférico. *Unasylva*. 173(44): 52-60.
- Sharrow, S.H. et Ismail, S. 2004. Carbon and nitrogen storage in agroforests, tree plantations, and pastures in western Oregon, USA. *Agroforestry Systems*. 60: 123-130.
- Sonwa, D. J., Weise, S. F., Tchatat, M., Nkongmeneck, B. A., Adesina, A. A., Ndoye, O., Gockowski J. (2001). The role of cocoa agroforests in rural and community forestry in Southern Cameroon. *Rural Develop For Netw Paper* 25g: 1–10.

- Sturges H A. (1926). The Choice of a Class Interval. Journal of the American Statistical Association, vol. 21, n° 153, mars 1926, p. 65-66
- Tufekcioglu, A., Raich, J.W., Isenhardt, T.M. et Schultz, R.C. (2003). Biomass, carbon and nitrogen dynamics of multi-species riparian buffers within an agricultural watershed in Iowa, USA. *Agroforestry Systems*. 57: 187-198.
- Valentini S. G. (2007). Evaluation de la séquestration de carbone dans des plantations agroforestières et des jachères issues d'une agriculture migratoire dans les territoires autochtones de Talamanca au Costa ; Mémoire de Maître es sciences (M.Sc) ; Faculté des Sciences de l'Agriculture et de l'alimentation, Université Laval Québec, (2007) 140 p.
- Winjum, J.K., S. Brown, and B. Schlamadinger. (1998). Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284
- Yabi I, Yabi Biaou F et Dadeignon S. (2013). Diversité des espèces végétales au sein des agro-forêts à base d'anacardier dans la commune de Savalou au Bénin. *Int. J. Biol. Chem. Sci.* 7(2): 696-706
- Yaméogo, G., Yélémo B., Traoré D. (2005). Pratique et perception paysannes dans la création de parc agroforestier dans le terroir de Vipalogo (Burkina Faso). *Biotechnologie, Agronomie, Société et Environnement*, 9p.
- Yenonfan N L, Gbaï I, Kooke G X, Djossou J-M, A C Kanninkpo et Tente B A H. (2020). Évaluation du stock de carbone dans les sols sous plantations d'ananas (*Ananas comosus*) biologique et conventionnelle sur le plateau d'Allada au sud du Bénin. *Rev. Ivoir. Sci. Technol.*, 35 231 – 246
- Zapfack, L., Engwald, S., Sonké, B., Achoundong, G., Madong, B. A. (2002). The impact of land conversion on plant biodiversity in the forest zone of Cameroon. *Biodiversity and Conservation*, 11, 2047-2061