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Assessment of carbon sequestration by mangrove plantations in Casamance (Oussouye, Ziguinchor, Senegal)

Benoît Alouise B MANGA[1]*, Ngor NDOUR[1], André Amakobo DIATTA[2,3] and Maurice DASYLVA[4]

[1]Département d'Agroforesterie, Laboratoire d'Agroforesterie et Ecologique (LAFE), Université Assane Seck de Ziguinchor, BP 523 Ziguinchor, Sénégal.
[2]Département Productions Végétales et Agronomie, UFR des Sciences Agronomiques, de l'Aquaculture et des Technologies Alimentaires (S2ATA), Université Gaston Berger, Saint Louis, BP 234 Saint-Louis. Sénégal.
[3]Centre de Suivi Ecologique, Dakar, Sénégal.
[4]Ecole Supérieure des Sciences Agricoles et de l'Alimentation (ES2A), Université Amadou Mahtar Mbow, BP 45927 Dakar Nafa VDN, Sénégal.

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The mangrove ecosystem abounds in fish and wood resources exploited by local populations for cooking and house construction. This has resulted in a strong loss of mangrove surfaces whose causes are explained by the combined action of natural and anthropic factors. To minimize the regression of the mangrove in Casamance, the Oceanium Association has organized since 2006 reforestation campaigns of mangrove trees. To date, the effectiveness of carbon sequestration by mangrove plantations has never been evaluated in southern Senegal. The present study aims to estimate the produced phytomass (biomass) and the aerial carbon stock of mangrove plantations to promote mangrove restoration actions. Three study sites were selected, namely the communes of Oukout, Mlomp and Diémbéring, in the Ziguinchor region (Senegal). They polarize 24 plantations distributed in 8 villages of the study area. The characterization of the mangrove plantations was performed from May to July 2020 using 2.5 m x 2.5 m plots, arranged alternately on each transect set up by plantation. The overall amount of carbon sequestered in the plantations in 2020 was estimated at 0.155 tC/ha for stems, 0.389 tC/ha for leaves and 0.501 tC/ha for roots. These results correlated with plant height allowed the development of a regression model to assess the total carbon stock in mangrove plantations. This model explained 81% of the total carbon stock in 7–10-year-old plantations. Results from this study suggest that mangroves can be dynamic and promising areas for climate change mitigation.

Key words: Mangrove, restoration, biomass, carbon sequestration, plantation.

INTRODUCTION

In Senegal, the largest mangrove formations are found in the Saloum Delta and in Casamance, mainly along the coastal lagoons (WWF, 2012). The mangroves in the department of Oussouye are one of the most beautiful formations in Lower Casamance and are also the seat of the main rural activities carried out in the department (rice growing, fishing, oyster and shellfish harvesting, beekeeping as well as ecotourism-related products and activities (Bassene, 2017). These mangrove formations constitute a particular ecosystem because of their functions, importance, and location. In addition to their recognized carbon sequestration potential, mangrove formations are home to many wildlife and floristic resources on which the riparian populations directly depend. Indeed, their ecological importance in terms of multiple trophic levels and coastal protection against marine erosion has been demonstrated by various authors (Aubé, 1999; Field, 1995; Jatobá et al., 2016; Ndour et al., 2014b; Pavithra et al., 2019).

The mangrove area which was estimated at 150,000 ha in Casamance in the early 1980s covered only 83,000 ha in 2006 (Bos et al., 2006). Like in Casamance region, there is an overall decline in quality and quantity of mangrove formations in the department of Oussouye. Diéye et al. (2022) studied dynamics of the mangrove formation in the department of Oussouye by remote sensing and reported a 47.1 and 90% decline for the dense and less dense mangrove facies, respectively, between 1972 and 1986. This strong loss of mangrove surfaces has been attributed to the combined influence of natural and anthropic factors (Sippo et al., 2018). The natural factors are mainly due to the rainfall deficit of 1970s and 1980s which resulted in land salinization and acidification and low natural regeneration (Diatta et al., 2021). This is mainly due to excessive wood cutting for fuel and construction and also hydro-agricultural developments such as the Affiniam dam (Tendeng et al., 2016). This latter has led to the modification of the hydrological regime of the river and the longer submersion of mangroves. In addition, the prolonged dewatering of the initial mangrove soils induced physicochemical and morphopedological modifications marked by a strong salinization and an acidification of the soils.

Because of the ecological, environmental and socioeconomic importance of mangrove formations for the local communities, local initiatives have been multiplied with the support of NGOs and programs such as IUCN, JICA, PADERCA, WFP and OCEANIUM (Cormier-Salem et al., 2017a) to promote the protection, rehabilitation and restoration of the mangrove formations. In this context, the "*Plant your tree*" program, initiated by a partnership between a Senegalese NGO, Oceanium, and a group of donors, the GEF, Carbon Livelihoods Venture Fund and private companies (Fondation Voyageur, Danone, Yves Rocher), was launched in 2006 in the Casamance estuary. The reforestation of mangroves was carried out due to the multiple products provided by these formations and used in human and livestock nutrition, pharmacopoeia, service, and energy wood. Today, the proven capacity of mangroves to sequester more carbon than other ecosystems has contributed to the recent interest in promoting mangrove formations for combating the negative impacts of climate change (Jadot, 2007). This potential for climate change mitigation is due to the capture of atmospheric CO_2 that is stored in the leaves, stems, and stilt roots of plantations (Diatta et al., 2017).

Moreover, mangroves trap an average of 1.4 gigatons of carbon per square kilometer per year (Laffoley and Grimsditch, 2009). In the Saloum delta, 1,936 tons of carbon were sequestered by a 2-year-old mangrove plantation in Djirnda (CCLME, 2014; Ndour et al., 2012a).

Despite the potential of mangrove formations to sequester carbon and mitigate the greenhouse effect, their carbon sequestration potential has never been evaluated in Casamance. After several years of mangrove reforestation in Casamance, it is important to assess the potential of high carbon sequestration by *Rhizophora* spp. plantations to better evaluate restoration and conservation programs in mangrove areas in Senegal. Thus, the general objective of this study is to improve the knowledge of *Rhizophora* spp. plantations in terms of produced biomass and carbon sequestration potential. Specifically, the aim is to evaluate the carbon sequestered by mangrove plantations and to develop a regression model to evaluate the carbon stock by plantations.

MATERIAL AND METHODS

Site description

The Department of Oussouye (Figure 1) is located between northern latitudes: 12°20' and 12°30' and western longitudes: 16°30' and 16°40'. It belongs to the southern eco-geographic zone whose forest resources are among the richest in the country in terms of both quantity and quality, and thus constitutes one of the most important ecosystems in Senegal. Oussouye is located in the extreme southwest of the Ziguinchor region and covers 891 km² or 12.14% of the area of the Ziguinchor region (ARDZ, 2016). It is bordered by the Casamance River to the north, the Republic of Guinea Bissau to the south, the Nyassia District to the east and the Atlantic Ocean to the west.

The department of Oussouye is characterized by a low relief and a small coastal portion consisting of lowlands of less than one meter (1 m) above sea level. This situation has favored marine intrusion in Casamance and the presence of mangrove forests (Marius et al., 1986). The climate of the department benefits from a low to very low monsoon circulation on the one hand and a low to medium circulation on the other hand over a period of five to six

*Corresponding author. E-mail: alouisebens@gmail.com. Tel: +221776734833.

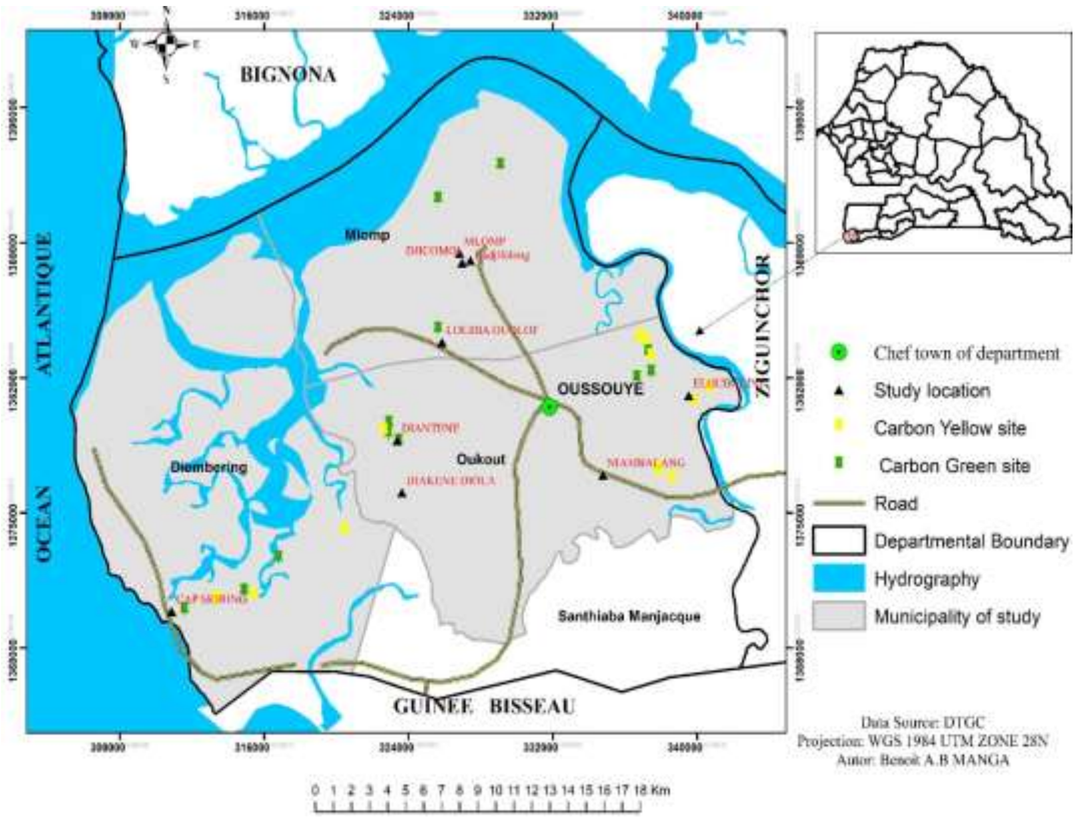

Figure 1. Location map of the Department of Oussouye (Ziguinchor, Senegal).
Source: Authors

Table 1. Summary of strata selection.

Sites	Stratum type		Strata sampling proportion
Oukout	Green	5	
	Yellow	10	
Diémbéring	Green	1	41%
	Yellow	1	
Mlomp	Green	6	
	Yellow	1	

Source: Authors

months (Sagna, 2005).

Site selection

The choice of the study area is based on the International Union for Conservation of Nature (IUCN) classification made in 2010 following an assessment of mangrove plantations. In the department of Oussouye, the communes of Oukout, Mlomp and Diémbéring are identified as sample units. The choice of these communes is motivated by the quality of the sites (green or yellow), and by their eligibility under the Clean Development Mechanism (Borner and Guissé, 2010).

Based on these two types of strata, the stratified random inventory was adopted in mangrove plantations. The green strata are favorable for the growth of *Rhizophora* spp*.* seedlings because their soils are muddy and have a moderate level of salinity. These strata are submerged by high tides during the dry season and are dominated by natural *Rhizophora* spp*.* (Cormier-Salem et al., 2017b). Yellow strata are moderately favorable for mangrove reforestation. Their soils are clayey-sandy, compact and submerged at high tide during the dry season (Cormier-Salem et al., 2017a). These strata are characterized by the presence of small mangroves (2 m), poor plant growth and limited natural regeneration.

The random sampling consisted in randomly selecting all eligible strata reforested between 2006 and 2012 and whose areas are between 3 and 5 ha. From these eligible strata, 58 plantations were pre-selected in all the communes and the selection of the number of plantations according to strata was determined by simple random sampling. Thus, 24 plantations out of 58 were pre-selected covering 8 villages, corresponding to a sampling proportion of 41% of the strata (Table 1).

In the selected strata, *Rhizophora* spp. is the only species recorded in the inventory plots. However, *Avicennia germinans* and *Laguncularia racemosa* were noted at the periphery of the strata and sometimes, exceptionally, in the center of the plantations. *Rhizophora* spp. belongs to the *Rhizophoraceae* family. The study of phenology allowed us to note that 100% of mangroves with propagules are of the species *R. mangle*.

Data collection

During the inventory of mangrove plantations, the sampling unit was a square plot of 2.5 m x 2.5 m (6.25 m^2), placed along a transect following the largest diagonal of each plantation (Figure 2) in accordance with the method developed by (Ndour, 2005;

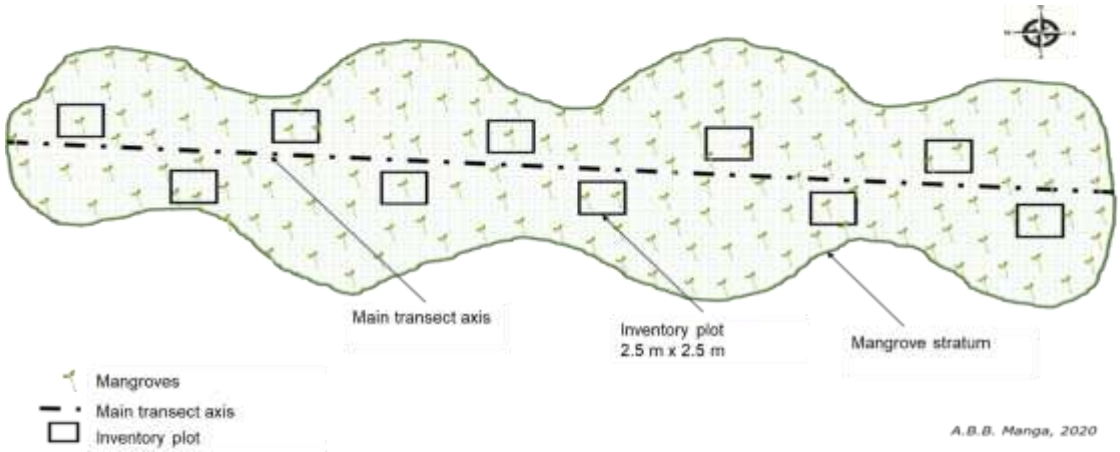

Figure 2. Layout of the sampling units.
Source: Authors

Figure 3. Delineation of the inventory plots.
Source: Authors

Deugué-Namboma, 2008). The transects were set during the rainy season of 2020. In each plantation, one (1) transect of 250 m length was set up, resulting in an average of 10 plots of 2.5 m x 2.5 m (Figure 2) following a series of distances between 5 and 25 m. The maximum distance of 25 m was chosen based on the smallest diagonal and the minimum distance of 5 m was chosen to avoid the edge effect of the bolongs which are defined as a saltwater channel, characteristic of the coastal areas of Senegal or Gambia, near estuaries (Ndour et al., 2014b). This method resulted in a sample size of 240 plots for all communes for a total area of plantations estimated at 110 ha of mangrove plantations. The GPS coordinates of the plantations were used to locate the sampling units. The surveyed area of the sampling units is estimated at 0.125 ha and represents 0.11% of the area of the reforested plantations. Figure 3 shows the delineation of the inventory plots.

Vegetation surveys

Within each plot, data were collected on floristic composition and dendrometric parameters (height, stem diameter and cross crown of each tree). The height of a plant, which corresponds to its height taken at the terminal meristem, is measured with a graduated yardstick for the larger sizes or with a metric tape for the smaller ones (Figure 4). The diameter at the base of the plants above the insertion point of the stilt roots is measured with a caliper**.** The floristic composition and the dendrometric data were collected from May to July 2020 in the department of Oussouye (Ziguinchor, Senegal).

The cross-sectional diameters of the crowns in meters of the trees are measured with a measuring tape. This measurement was used to estimate the crown area of mangrove plantations by projecting their crowns on the ground in reference to the area of the vegetation survey. The percentage of ground cover was calculated using the following formula.

$$\textit{Ground cover percentage}\ (\%) = \frac{\Sigma\ \textit{ground cover of individuals in the sampled area}\ (m^2)}{\textit{Sampled area}\ (m^2)}\ x\ 100$$

Data collection on the dynamics of mangrove plantations

All trees in the plots were counted (replanted, regrown, dead) during the duration of the study (from May to July 2020) and data collection from 2010 helped determine the density, mortality, and evolutionary trend of the plantations. The data collected on the dynamics of mangrove plantations were performed at the same

Figure 4. Height measurement of Rhizophora spp. Plants.
Source: Authors

Figure 5. Clear cutting of Rhizophora spp.
Source: Authors

Figure 6. Weighing of the harvested biomass.
Source: Authors

sites for 2010 and 2020.

The total number of plants includes both young plants and adult plants. Thus, the mangrove plants in a state of fruiting are considered as seedlings and those without stilt roots in a "vegetative" state as regenerated (regrowth). The observed density is obtained by the ratio of the total number of individuals in the sample divided by the sampled area.

$$D = \frac{N}{S}$$

With N= total number of individuals in the considered sample and S = surface of the sample in ha.

Quantification and estimation of biomass

In each plot, the height of all the plants was measured to determine the average plant height of the plot. Based on the average plant height, two plants close to the average height were randomly selected for the evaluation of the above-ground biomass that is a total of 20 plants per site, that is, 480 plants for the entire study area. A clear cut (Figure 5) was made following the identification of the two average height plants in the plot. The different compartments made up of leaves, stems and roots were weighed in their entirety (Figure 6), then a sample was taken from each compartment. The samples cut into leaves, stems and roots are weighed on the same day using a CH-50K100 electronic balance with a precision of 1 g and a capacity of 50 kg. In the laboratory, these samples are dried in an oven (Figure 7) at 105°C for 72 h and between 96 and 120 hours depending on the compartments collected.

For all sample categories, a minimum of 5 randomly selected samples were weighed daily until weight stabilization. Stabilization took three days for leaves and one week for stems and roots depending on sample size. From the selected samples, the moisture content (MC) is calculated;

Figure 7. Oven drying of samples.
Source: Authors

$$MC\ (\%) = \frac{Wet\ sample - Dry\ sample}{Dry\ sample}\ x\ 100$$

Drying these samples allowed us to determine the fresh-to-dry biomass conversion factor for each compartment. This conversion factor is the average ratio (Ra) obtained from weighting the dry mass of the sample by their fresh mass:

$$R_a = \frac{Dry\ sample}{Wet\ sample}$$

According to (Picard et al., 2012; Rondeux, 1999)
Thus, the quantity of dry biomass produced by the plantations is estimated by multiplying the fresh biomass of each compartment by this average ratio (Ra), that is:

$$Q_{ms} = BTF\ x\ Ra$$

With $\mathbf{Q_{ms}}$ = amount of dry matter; **BTF** = total fresh biomass of an entity of the species. The total biomass is calculated by summing the biomass of all compartments.

Assessment of carbon sequestration

The amount of carbon sequestered is estimated from the dry biomass obtained. This biomass is converted using the conversion factor of the carbon fraction of dry matter into living biomass 0.47 according to (GIEC, 2006) based on the following formula:

$$Amount\ of\ carbon = Dry\ biomass\ x\ 0.47$$

Regression analyses relationship between growth parameters and carbon sequestration

The dendrometric measurements are used to develop a regression equation between growth parameters and the amount of carbon sequestered based on the following relationships:

$Y_1 = a + bH$ and $Y_2 = a + bC^2H$

With **Y=** amount of carbon sequestered, **H**= total height and **C** the circumference. These models allow relating to the sequestered carbon (Y) and the explanatory dendrometric parameters **H** and **C^2**H. These linear models led to regressions of the type: Y_1= a + bH and Y_2 = a + bC^2H, where a is the intercept of the line and b its slope. These partial regression coefficients were determined using SAS JMP Pro version 15.0.0 statistical software (SAS Institute Inc., Carey, NC) (Proust, 2016).

Data processing and analysis

The Excel spreadsheet was used to determine the observed density, biomass conversion factor, amount of dry biomass and carbon sequestered in the plantations. The data were analyzed using SAS JMP Pro version 15.0.0 statistical software (SAS Institute Inc.). This statistical analysis tool was then used to perform analyses of variance (ANOVA) for plant and carbon sequestration parameters and to establish a regression relationship between carbon and dendrometric parameters (C and H). When assumptions of normal distribution of data and homoscedasticity were not met, data were transformed using Box–Cox power transformation. Treatment means were separated using Fisher's protected LSD test at α **=** .05 level of probability when values were significant. Correlation analyses were performed to ascertain the relationships between the amount of carbon sequestered and plant height as well as the square circumference * height.

RESULTS

Floristic composition of mangrove plantations

The analysis of Figure 8 revealed that Oukout had a significantly higher ground cover (16%) than Mlomp and Diembering sites in 2020. The crown area of mangrove plantations in Mlomp and Diembering were, respectively, 37 and 39% lower than the percent ground cover in Oukout. The cross-sectional diameters of the mangrove plantation crowns revealed significant differences ($p<0.05$) between sites.

Estimation of the produced biomass

The amount of fresh biomass at the sites is estimated to be 0.597 t/ha for stems, 1.711 tons per hectare for leaves and 2.292 tons per hectare for roots in 2020. The conversion factors for this fresh biomass are 0.55 for stems, 0.48 for leaves and 0.46 for roots, respectively. Evaluation of dry matter from conversion factors yielded 0.331 t/ha for stems, 0.828 t/ha for leaves and 1.066 t/ha for roots for the studied mangrove plantations.

The analysis of variance for the amount of dry matter per plant between sites reveals a significant difference (P-value =5,25 $^{e-05}$). The analysis of the Figure 9 revealed that 0.23592 t of total dry biomass was recorded in Oukout, 0.01894 t in Mlomp, and 0.00618 t in Diembering. Consistently, Oukout site recorded the

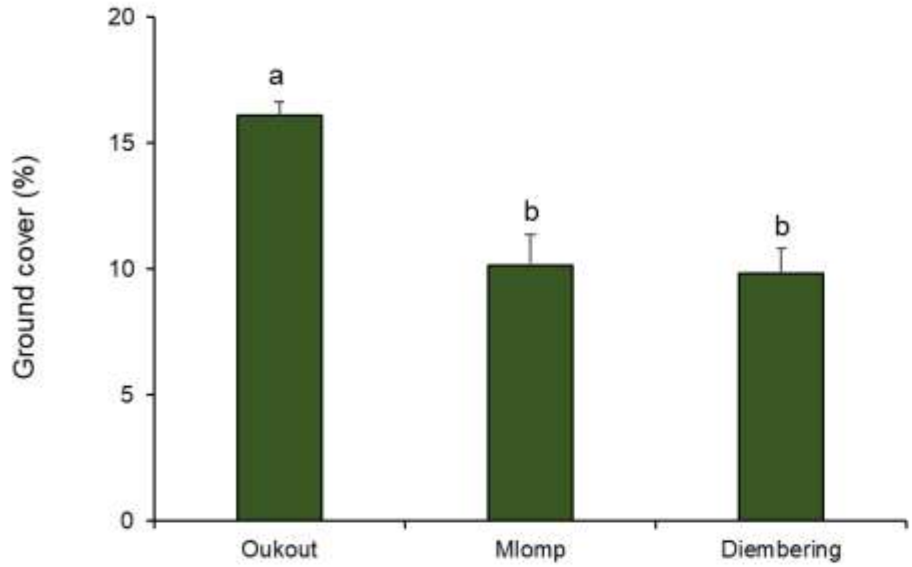

Figure 8. Mean percentage of ground cover of mangrove plantations in Oukout, Mlomp and Diembering. Treatments connected by dissimilar letters are significantly different at α = 0.05 according to Fisher's protected LSD and error bars represent standard error of the mean.
Source: Authors

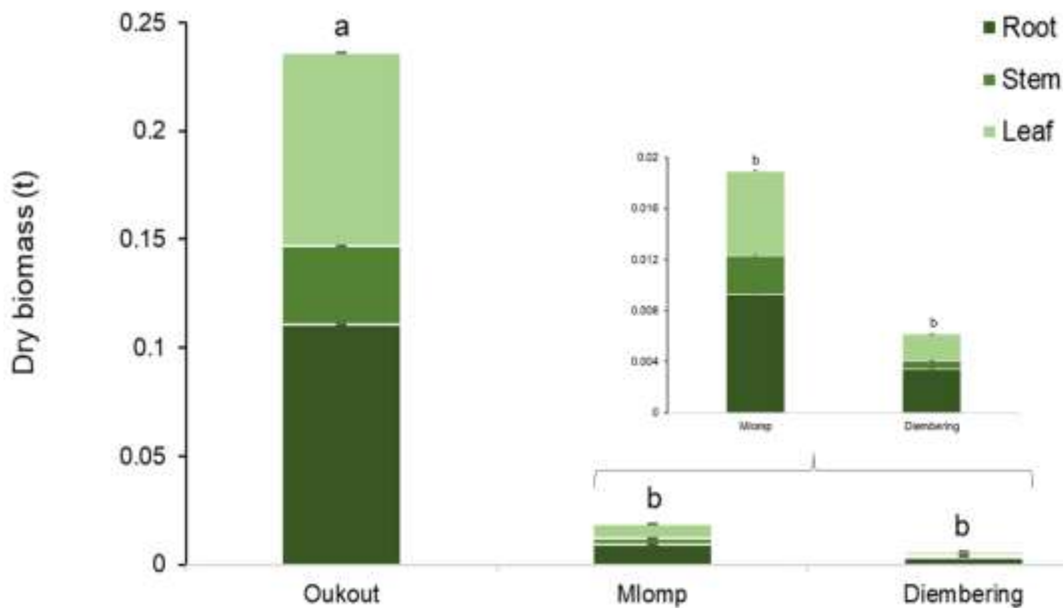

Figure 9. Dry biomass of mangrove formations in Oukout, Mlomp and Diembering. Treatments connected by dissimilar letters are significantly different at α = 0.05 according to Fisher's protected LSD and error bars represent standard error of the mean.
Source: Authors

highest dry biomass per organs compared to Mlomp and Diembering. Specifically, the root, stem, and leaf dry biomass were respectively 0.11051, 0.03643 and 0.08898 t. The dry biomass of the mangrove organs was significantly lower in Mlomp and Diembering and was 0.00928 t and 0.00341 t for roots, 0.00303 t and 0.00065 t for stem, and 0.00663 t and 0.00212 t for leaf biomass, respectively.

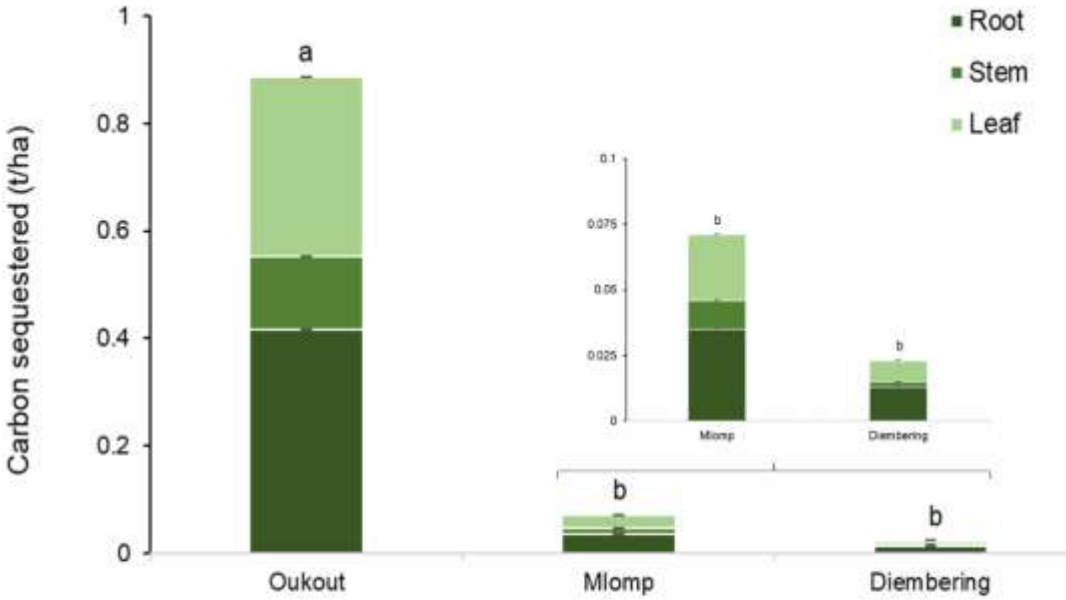

Figure 10. Carbon sequestered by mangrove formations in Oukout, Mlomp and Diembering. Treatments connected by dissimilar letters are significantly different at α = 0.05 according to Fisher's protected LSD and error bars represent standard error of the mean.
Source: Authors

The amount of dry biomass per individual obtained by stratum in the plantations of the sites differed significantly for all sites in Oukout (P-value =2.16 $^{e-07}$), Diémbéring (P-value =1.75 $^{e-07}$) et Mlomp. This also shows a variation in mean biomass per plant for Oukout (0.00103±0.00134t), Diémbéring (0.00012±0.00043t) and Mlomp (0.00036±0.00080t).

Carbon sequestered in mangrove plantations

The overall amount of carbon sequestered in the sites is estimated to be 1.046 tonnes of carbon per hectare (tC/ha). With reference to the compartments, stems provided 0.1554tC/ha leaves 0.3891 tC/ha and roots 0.5010 tC/ha. The analysis of variance of the overall amount of carbon sequestered reveals a significant difference (P-value <.0001*) between sites. The Figure 10 revealed that Oukout sequestered 0.921 tC/ha while Mlomp and Diembering only recorded 0.086 and 0.038 tC/ha, respectively. Similar to the dry biomass per organs of mangrove plantations, the plants organs of Oukout had higher carbon sequestration values than Mlomp and Diembering. The root, stem, and leaf organs, respectively, sequestered 0.422, 0.16, and 0.339 tC/ha. These values correspond to 1000% more carbon sequestered for each organ at either Mlomp Diembering. The average amount of carbon sequestered per individual in *Rhizophora* spp. plantations is 0.000379± 0.00067t at these sites. Figure 4 show the carbon sequestered by mangrove formations in Oukout, Mlomp and Diembering.

Regression relationship between height and sequestered carbon

The analysis of the graph (Figure 11) shows a good relationship between the amount of carbon sequestered from *Rhizophora* spp*.* and the height of the plants. This graph shows that plant height has a positive relationship with the amount of carbon sequestered (p-value < 0.0001*). The coefficient values are characterized by a constant at the origin of -0.001702, a positive slope of +0.0025368 and a coefficient of determination R^2 = 0.81 (Prob. F<.0001*).

Regression relationship between C²H and sequestered carbon

The regression relationship between C²H and sequestered carbon is presented on the Figure 12. The analysis of this graphs shows a significant relationship (p-value < 0.0001*) between the amount of carbon sequestered from *Rhizophora spp.* and the parameter C²H. Therefore, the combination of diameter and height is positively related to carbon sequestration. The model obtained is characterized by a constant at the origin of -0.000188, a positive slope of +0.6897366 and a coefficient of determination R^2 = 0.77.

The analysis of simple regression analyses shows a

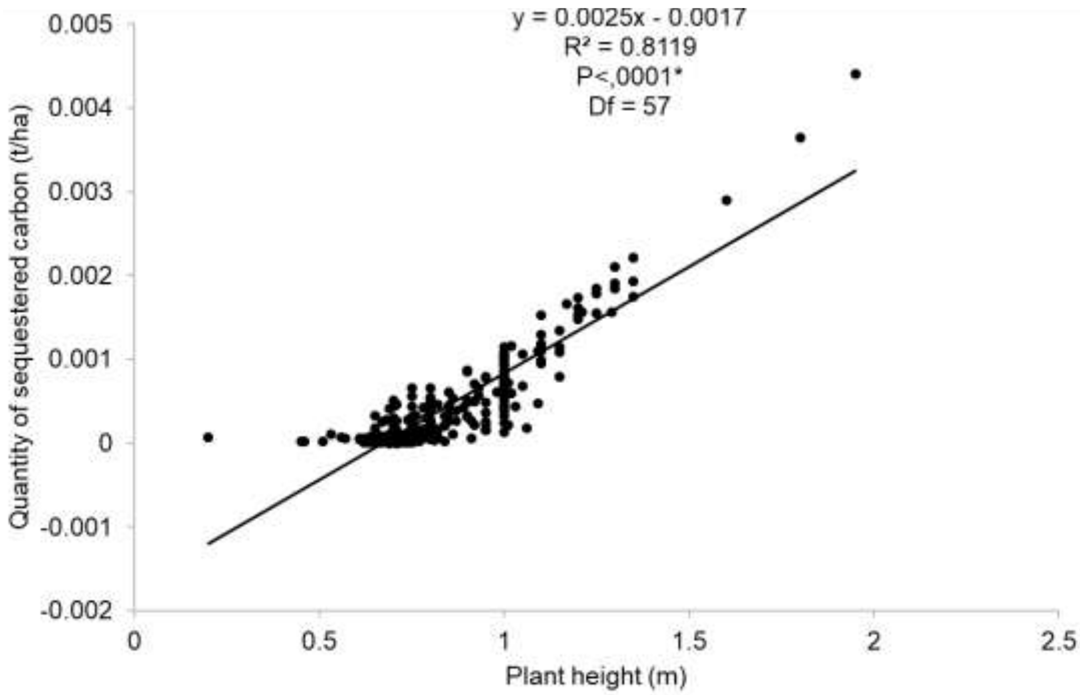

Figure 11. Regression of carbon sequestration with plant height.
Source: Authors

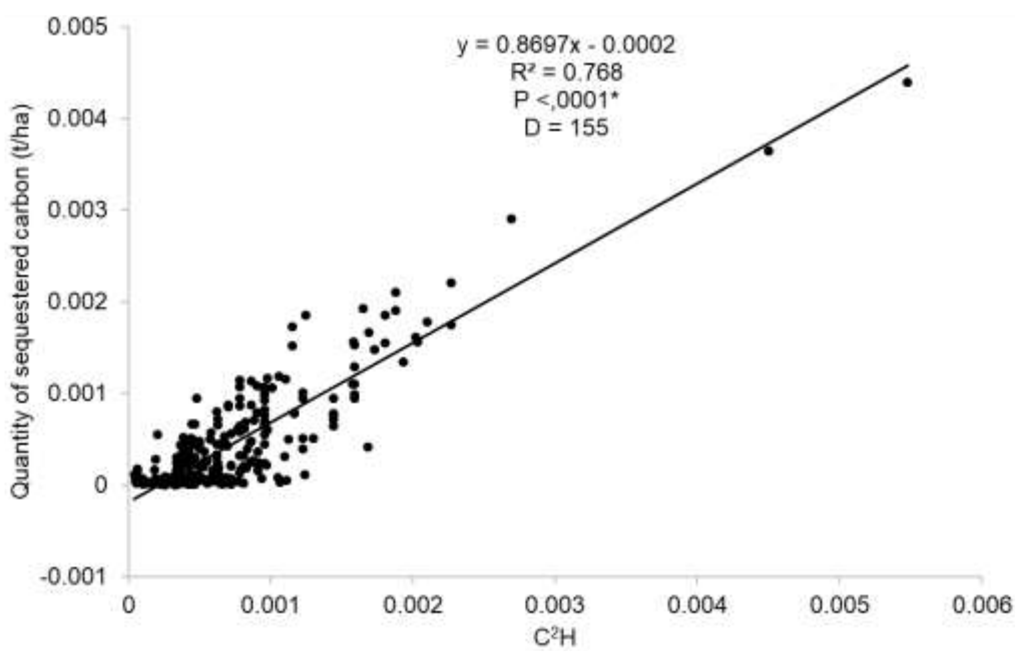

Figure 12. Regression of the amount of carbon sequestered as a function of the square circumference * height of the plants.
Source: Authors

good fit between sequestered carbon and height (R^2 = 0.81). On the other hand, the combination of the two parameters (C^2H) determines a regression relation of less precision with (R^2 = 0.77). It appears from these two types of analysis that these two models can be validly used to evaluate the carbon sequestered by mangrove plantations in Casamance.

DISCUSSION

Floristic composition and structure of mangrove plantations

The study showed a mono genus presence of *Rhizophora* compared to the species *Avicennia germinans*. This result confirms those of various authors who have reported that mangrove plantations are often mono-specific in some regions (Diedhiou et al., 2015; Ndour et al., 2018; Cormier-Salem et al., 2017b). The monitoring of phenology showed a dominance of *R. mangle* in the plantations although five (05) other species are present in the study area. These are *Rhizophora racemosa*, *Rhizophora harisonnii*, *Avicennia germinans*, *Conocarpus erectus* and *Laguncularia racemosa*. These monospecific plantations can be explained by the use of a single species during mangrove restoration campaigns. However, this tendency is far from deliberate, as *R. mangle* is the mangrove that produces more propagules from the Saloum Delta to Casamance according to (Ndour et al., 2014c).

Analysis of the amount of biomass produced by the plantations

Predicting biomass using regression equations is key to estimating the contribution of various forest ecosystems to the carbon cycle (Picard et al., 2012). Comparison of biomass conversion factors shows significant variation in moisture between compartments of the aerial pool. As a result, the factor of each compartment was retained for the conversion of fresh biomass to dry biomass following the approach of Ndour et al. (2014a) in the Saloum Delta.

Dry biomass by compartment suggests that root biomass is more important than stem and leaf biomass. This may be due to the degree of lignification of rhizophores and their importance in stabilizing mangroves on mudflats. This result corroborates those of Ndour et al. (2014c) who showed that low compactness can explain the development of a stronger root structure and scope for mangrove tree anchoring and stability in the environment.

A comparison of dry biomass between sites shows that the Oukout plantations have a greater quantity of dry biomass. These results can be explained by the difference in soil quality (muddy) and the proximity of the bolongs, unlike Diémbéring and Mlomp plantations. This difference in biomass according to soil characteristics is confirmed by GAYE, (1984) who maintains that the development of a plant depends on the conditions of the environment and its photosynthetic capacity.

Assessment of the amount of carbon sequestered

The estimation of aboveground biomass produced by mangrove plantations showed a strong relationship between growth parameters (height and diameter) and sequestered carbon. The result obtained confirms those of Deugué-Namboma (2008) and Ndour et al. (2012a) which indicate 1.9 tons of carbon sequestered by a 2 year old mangrove plantation in the Saloum Delta. Estimating the amount of carbon sequestered in relation to height gave the best regression correlation compared to that of the square of circumference time’s height (C^2H). This result could be due to the variation of stem branching order with size and roots with age.

Analysis of carbon sequestered by compartments shows that roots sequester more carbon than leaves and stems. This result confirms the findings of Ndour et al. (2014c) that showed that root biomass is always slightly greater than that of other parts of the plant. Furthermore, there is a difference in carbon stock between the Oukout plantations and those in Diémbéring and Mlomp. This result is in agreement with those of Murray et al. (2011) who also reported that apart from the inorganic carbon in the soil, the rest (organic carbon) is found in the living biomass. Indeed, sites where the amount of dry matter is highly significant, give equally highly significant carbon sequestration as demonstrated by the GIEC, (2006).

The mangroves of Casamance thus play the role of carbon sink, contributing to lessen the causes of global warming. It is undeniable that mangroves have a strong capacity to sequester carbon, superior to other ecosystems. The evaluation of carbon sequestration in mangrove plantations in the Saloum Delta (Senegal) has shown that they can sequester 1.936 tons of carbon in two years (Deugué-Namboma, 2008). In Senegal, over the 30-year period, an amount of 81.132.86 tCO2-e is expected due to the reforestation carried out in Casamance and in the Saloum delta (Cormier-Salem et al., 2016). Global terrestrial vegetation has been projected to sequester 112–169 PgC (1PgC = 1015g carbon) each year, which plays a vital role in global carbon recycling (Sha et al., 2022). The findings suggest that optimizing land management can sequester higher, if not the highest, potential carbon from the managed vegetation, representing a promising way to mitigate climate changes.

Regression analyses for sequestered carbon assessment

In this study, it was essential to understand the different parts where mangroves fix and store carbon and the role of mangroves in the carbon cycle. Like other woody plants, mangroves consist of above-ground and below-ground biomass of carbon fixation and storage assimilated by mangroves and returned to the atmosphere via above- and below-ground respiration.

This study shows a difference in the accuracy of the regression models obtained depending on the growth parameters tested. According to the partial coefficients of regression (intercept, slope) and the coefficient of determination, a significant difference was noted between the regression models. The coefficient of determination (R^2) is higher for the model that estimates sequestered carbon as a function of height than the model that estimates it as a function of the square of the circumference and height, that is, C^2H. These results indicate that height influences plant biomass as well as the C^2H parameter to a lesser extent.

The models obtained with $Y_1 = a + bH$ gives a higher accuracy with a coefficient of determination $R^2 = 0.81$. This regression model remains lower than the cubing rate model ($R^2 = 0.968$) developed in the Saloum Delta by NDOUR et al., (2014). However, the models obtained are more accurate than those developed in the Republic of Guinea ($R^2 = 0.63$) by Arsenault (1993). The two equations (Y_1 and Y_2) from this study are substantially similar to those found by Clough and Scott, (1989) in Queensland with more significant regression relationships ($R^2 = 0.746$ et $R^2 = 0.847$) found in the Mangoky Delta. However, besides longitudinal and latitudinal factors our regressions are less accurate than those obtained by Suzuki and Tagawa (1983) as well as (Rakotomavo, 2018) in southern Japan with regression relationships of $R^2 = 0.973$ et de $R^2 = 0.959$.

Conclusion

The study on the assessment of carbon sequestration by mangrove plantations in Casamance revealed that the plantations have a significant amount of dry matter. This quantity of dry biomass shows a good carbon sequestration in Casamance. These results sufficiently demonstrate the importance of restoring mangrove ecosystems through the mangrove planting technique. In addition, this study revealed that young mangrove plantations in full growth could be potential carbon sinks.

Despite observing promising results, further research in the quantification of the aboveground biomass in all eligible plantations in Casamance and the study of edaphic factors to establish a relationship between the species and the type of soil adapted to its reforestation will be required for the development and prosperity of the carbon market in mangrove ecosystems in Senegal.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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