Chapter 2
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Carbon Stocks Potential in Regenerating Trees of the Tropical Coastal Forest Ecosystems

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ABSTRACT

Estimation of carbon in the regenerating tropical coastal forest is needed to support conservation and forest monitoring strategies. This chapter presents the determined carbon stocks in regenerating species across forest sites subjected to deforestation because of crop-farming and livestock grazing. The study used thirty-three independent measurements of tree carbon stocks from thirty-three tree families found in the coastal zone of Tanzania. The vegetation was inventoried using a floristic survey of the woody component across intact, crop agriculture and livestock disturbed land-use sites. The biomass was then estimated by employing the existing allometric equations for tropical forests. Thereafter, the above-ground stored carbon was quantified on the sampled tree species found in each land uses. The tree varied ($p \le .05$) in carbon stock across species and land uses. The average carbon (Kg/ha) stored in the regenerated adult trees was 1200 in IFS, 600 in ADS, 400 in LDS. Saplings had 0.43 in LDS, 0.07 in ADS and 0.01 in IFS. Also, seedlings showed an average of 0.41 in IFS, 0.22 in ADS and 0.05 in LDS. It shows that crop-agriculture highly affects the regeneration potential of trees, biomass accumulation and carbon stock than livestock grazing. To restore the carbon storage potential of coastal tropical forests, crop-agriculture must be discouraged, while livestock grazing can be integrated into forest management. Indeed, further studies are required to gauge the integration levels of any anthropogenic activities, so that the natural capacity of coastal tropical forests to regenerate and stock carbon is not comprised further.

Keywords: Carbon; land uses; sequestration; sink; regeneration.

1. INTRODUCTION

Life on earth depends largely on forest ecosystems and their services [1,2,3]. In nature, forest ecosystems are the major terrestrial reservoirs of carbon in the form of plant biomass and soil organic matter [4,5,6,7]. These ecosystems are among the locally and globally recognized sources or sinks of carbon in the remaining or regenerating forests [2,5,8,9]. Forests play crucial roles in regulating the global biogeochemical cycles [7,8,10,11,12]. Indeed, forest ecosystems play important roles in reducing atmospheric carbon dioxide and hence regulating climate change [13,14,15]. Thus, forests are among the vital components of the global ecosystems in addressing climate change, the most pressing issue in the world today [8,16,17]. Although forests are important sources or sinks of carbon, they are frequently affected by human activity pressure [18,19,20]. Regionally and globally, human activities disturb forest ecosystems through land cover and land use (LCLU) changes, hence causing forest ecosystems to function as carbon sources rather than sinks [21,22,23,24,25]. These activities have contributed to the introduction and development of secondary forests in the tropics [26]. Human activities cause land cover and land use changes that pose challenges on the capacity of the forest to regenerate, function, and offer various ecological services including the capacity to function as carbon sources and sinks [27,28,29]. However, there is little information about the amount of carbon in regenerating forest ecosystems along with the tropical coastal forests (in this study referred to as tropical coastal forests). Therefore, it is important to estimate carbon stocks of the regenerating species for understanding their contribution to the global carbon stock and in addressing climate

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change [30]. Carbon loss in forest ecosystems is the outcome of anthropogenic activities [8,25]. Deforestation and degradation of terrestrial forest ecosystems are the main factors for the loss of carbon in tropical forests [25,31,32]. Deforestation, degradation and poor forest management reduce the capacity of forest ecosystems to store carbon [33]. These activities bring the so-called anthropogenic causes of global warming [6,32]. The loss of carbon is based on the fact that disturbances affect the structure of forests including the type, size, age, species stand and species diversity, the parameters, which are directly associated with the storage of carbon in forest ecosystems [10,12,34]. Also, disturbances in the forest affect the belowground carbon stock that includes soil, litter, and roots [32,35,36]. Although documentation shows that the below-ground carbon sink of trees harbors larger quantities of carbon, this sink capacity is limited by many factors such as the magnitude of historic carbon loss, a higher rate of decomposition because of change in climate, and different land uses and management [23,37].

The land-use forms such as cultivation and livestock grazing expose soils to loss of the sequestered carbon in the terrestrial forest ecosystems [20,23]. These activities disturb the capacity of the below-ground carbon storage system, which stores the largest terrestrial carbon pool (i.e. storing more than double the quantity of carbon in vegetation or the atmosphere) [38]. Unquestionably, crop-agriculture and livestock grazing are among the major activities contributing to forest LCLU changes in the tropics [19,22,39]. These activities contribute substantially to alter carbon storage in forest ecosystems [40,41]. Crop-Agriculture and livestock grazing fail to support forest ecosystem sustainability and to restore the degraded ecosystems [42,43].

To allow regeneration in the disturbed and degraded ecosystems, different ecosystems management options are implemented, in which exclusion of anthropogenic activities are implemented in many parts of the world [44]. Exclusion is sought to contribute in allowing forests to regenerate naturally and thus many of the existing forests species in the tropics are secondary [45]. Existing studies have quantified the amount of carbon in various ecosystems. For example, carbon storage in grasslands ecosystems [40,44], carbon storage in the tropical forests [34,35], land-use changes and carbon emissions in terrestrial ecosystems [18,21]. Other studies include land-use changes, carbon sequestration and biodiversity [17,22,31,46] and carbon storage in plantations [6,33], while allometric models for species located in the coastal zone of Tanzania have been presented in [43]. Across all these studies, it is indicated that trees play a big role in carbon storage. These studies show that an increase in the secondary natural forest increases carbon storage above and below the ground [18]. Nevertheless, literature shows that land-use conversions affect the capacity of forests to store carbon [22]. To revert the trend of forest loss and impacts on carbon storage, regional and global efforts are increasing to implement land-use changes that aim at restoring biodiversity and the degraded forest ecosystems [8,45]. These efforts promote the re-growing of forest species, thus automatically facilitating the regeneration process and creation of carbon sink [4,47]. The knowledge about forest and carbon interplays in the tropics provides information for the management of these vital ecosystems, which dominate the role of controlling the global carbon cycle based on both carbon flux and the volume stored in these forests [48].

This chapter presents a piece of baseline information for future comparisons of carbon stock after the exclusion of human activities bearing in mind that carbon sequestration increases with forest restoration age [22]. The information generated in this work provides basic information to operationalize value to land managers and policymakers as they facilitate monitoring of tropical forest carbon dynamics and further motivation to conserve tropical forests for reducing net CO2 emissions [2,25,33,35]. In the present study, the author examined the variation and established the relationships between regenerating tree carbon storage across intact forest sites (used as control) and forests disturbed land-use sites after the exclusion of crop and livestock production. The author focused on estimating carbon in the above-ground biomass of seedlings, saplings and adult trees because the above-ground carbon is stored in tree biomass [7,35]. Specifically, the study focused on analyzing the difference in carbon sink across intact and disturbed sites because of different LCLU cause variation in the amount of carbon held in terrestrial ecosystems [14,18,48]. The following hypothesis was tested. Carbon storage differs between regenerating species in closed forest sites from the sites disturbed by crop-agriculture and livestock grazing. This work was carried out to find the answer to the following question: How carbon varies across regenerating species of forest sites subjected to different land uses and management?

2. LOCATION AND CARBON STOCKING

2.1 Location

The information presented in this chapter were obtained from the forest located along the coastal zone of Tanzania. The study area was the Uzigua Forest Reserve (UFR) located in Bagamoyo and Chalinze Districts in the Pwani Region of Tanzania (Fig. 1). This forest is located within 100km from the Indian Ocean. Specifically, the forest is found between 60°00' and 60°15' and 38°00' to 38°15'E [49]. The forest is characterized by being affected by human activities mainly crop-agriculture, tree harvesting for charcoal and timber production, livestock grazing pressure and encroachment for human settlements. It is because of the historical characteristics of these anthropogenic activities, therefore, UFR was purposely selected for this study.

2.2 Inventory of Tree Species

Ground forest inventories were carried out to measure and identify tree species sub-categories (i.e. seedlings, saplings, and adults) from IFS, ADS and LDS [50]. Trees population density, diameter at the breast (dbh) and height were measured for determination of basal area and bio-volume of each species. These determined variables were used for the allometric equation by relating wood volume to stem diameter at breast height [51]. A random selection of sites and the establishment of sampling plots were carried out after the stratification of the land-use sites. Forty-five (45) quadrats of 25 m × 25 m size were laid down for a collection of adult trees data, while nested plots of 2 m × 2 m (within the established 25 m × 25 m plots) were laid down for a collection of seedlings and saplings data [52,53]. Stems with a diameter of ≥ 20 cm at breast height (dbh) (approximately 1.34 m height above the ground) were counted as trees. All the tree species with < 20 cm diameter were considered as regenerates in the following subdivisions: (i) seedlings included only trees with < 0.40 m height and (ii) saplings included all the trees from ≥ 0.40 m to < 1m heights as adapted from [53]. Seedlings, saplings and adult trees were identified and recorded in each of the same established sampling plots across the sites as adapted from [34]. Photos of trees species were taken in the field to verify the accuracy of the field plant identification.

2.3 Quantification of Carbon

2.3.1 Computing trees stand parameters

To quantify carbon from the regenerating trees, the author adopted a non-destructive method in collecting species parameters and then computed the biomass and carbon for each seedling, sapling and adult trees [4,5]. From tree species checklists (i) number of live trees per unit area (N/ha), (ii) basal area (BA) of live trees (m2/ha) and (iii) volume of live trees (m3/ha) were calculated following a methodology laid down by [54]. Computation of BA was carried by by = $((h)\ \times)/4$ (Eq.1); where dbh = diameter at breast height and π = 3.14; the volume was calculated as = h (Eqn. 2); where v = volume estimation (m3/ha), g = basal area of the tree/seedling/saplings (m2/ha), h = height of the tree (m) and f = form factor (0.5). The form factor of 0.5 was used as an average for natural forest factor, which ranges between 0.4 and 0.6 [30,55]. The computation of these factors was done by ensuring that each land-use class is represented [56].

2.3.2 Determination of tree biomass and carbon content

Tree biomass and carbon pools were determined using allometric equations from the GlobAllome Tree platform (The international platform for tree allometric equations) [51,57]. The author used the equations particularly developed for the tropical tree species as in [51,58]. These models were used in computing the above ground (ABG) and carbon stock per each tree species, on each sampling plot [4]. The AGB was estimated as AGB = V × WD (Eqn.3); whereby V is the bio-volume and WD is the wood density for each tree species [33,57,59]. To maintain the non-destructive methodological approach (because we were not permitted to harvest any part or whole plant from the reserve, except photographing as shown in Fig. 2), the WD for each species was adopted from [43,60,61]. Carbon stock per each species in each sampling plots was estimated as C = TB × CF (Eqn.4), whereby C is the carbon, AGB is the above-ground biomass and CF is a carbon fraction of dry matter (default = 0.5), tonnes of carbon [62].

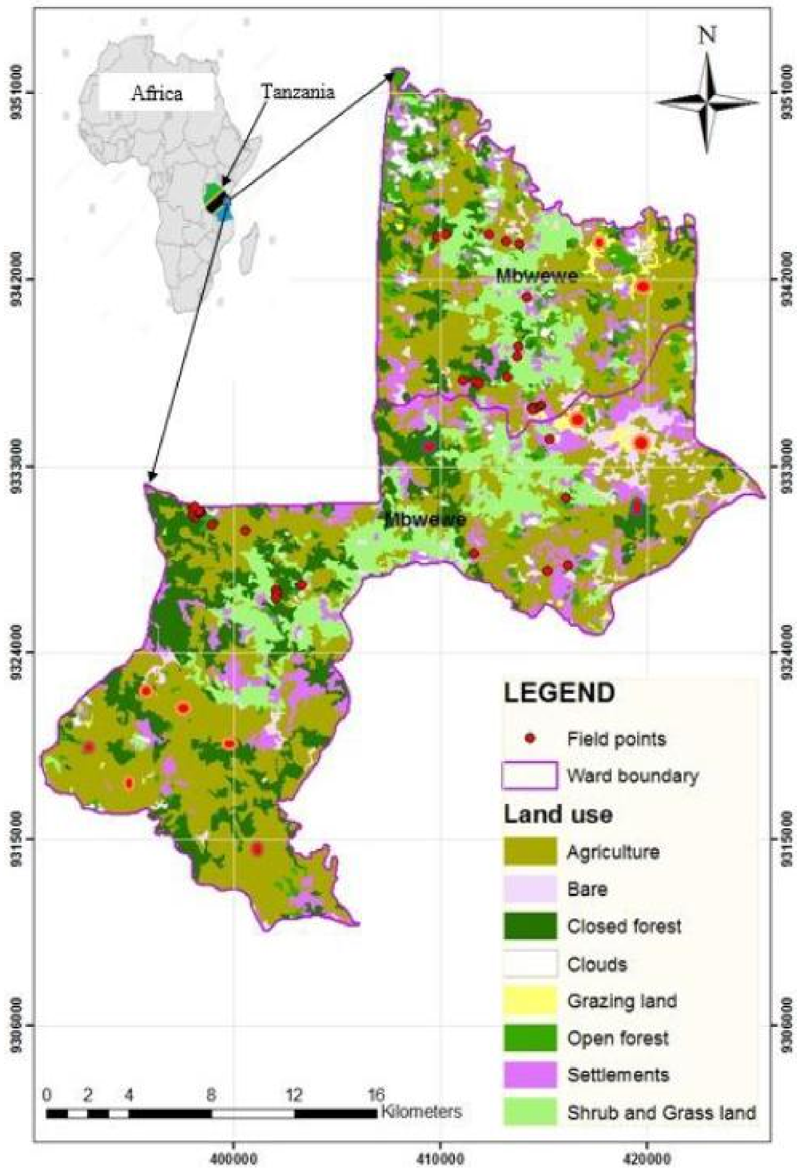


Fig. 1. A map of study area

3. TREE SPECIES AND CARBON STOCKS

3.1 Tree Families and Species Studied

The number of species, which were recorded for carbon stock estimates were 33. These species were from 14 families including Fabaceae (39%), Moracea (13%), Chrysobalancea, Combretaceae, Guttiferae) and Malvaceae (each by 6%), Asteraceae, Ebenaceae, Lamiaceae, Lauraceae, Meliaceae, Rhamnaceae, Rhizophoraceae and Rubiacea each being represented by 3%. Throughout the figures, each tree species was represented in Arabic numbers as arranged in Fig. 2.

3.2 The Mean of Carbon Stock across Tree Sub-categories

The mean of carbon stock (Kg/ha) across the tree sub-categories were 1.22E3 ± 101.59, 4.72E2 ± 60.37 and 6.33E2 ± 90.28 for adult trees in IFS, ADS and LDS respectively. The mean carbon for seedlings was 0.5 ± 0.01, 0.22 ± 0.03 and 0.41 ± 0.05 Kg/ha in the IFS, LDS and ADS respectively. The mean carbon in saplings was 0.01 ± 0.01, 0.07 ± 0.01 and 0.43 ± 0.04 Kg/ha in IFS, LDS and ADS respectively.

There was a significant difference in carbon stock between adult tree in IFS and ADS with the mean variation of 7.46E2 ± 88.70, at t = 8.41 and p <. 001. There was a significant difference between carbon in adult tree found in IFS and LDS as indicated in the mean of 5.84E2 ± 157.65, t = 3.71, p < .001 and the difference of carbon in adult trees in ADS and LDS showed a significant value of 1.62E2 ± 116.93, t = 1.38, p <.177.

In regards to seedlings, the difference of carbon showed higher values between seedlings in IFS and ADS with the mean variation of 0.17 ± 0.03, t = 6.59, p < .001, carbon in IFS and LDS variation was low with the mean value of 0.36 ± 0.04, t = 8.02, p < .001, while carbon in ADS and LDS had a mean difference of 0.19 ±0.05, t = 3.44, p <.002. The mea difference for saplings between IFS and ADS was 0.05 ± 0.01, t = 7.34, p < .001. The variation between IFS and LDS saplings carbon stock showed the mean of 0.42 ± 0.04, t = 10.75, p <.001 and that between ADS and LDS was 0.36 ± 0.04, t = 8.86, p< .001.

3.3 Saplings and Seedlings Carbon Stock across Species in IFS

Carbon stock varied across species. Higher carbon stock was recorded in saplings than in seedlings in IFS. Higher carbon stock was observed in saplings of *Afzelia quanzensis*, *Brugueira gymnorhiza* and *Milicia excelsa* with carbon ranging between 0.05 Kg/ha to 0.19 Kg/ha, while the seedlings carbon stock was dominated by *Brachystegia boehmii*, *Diospyros abyssinica* and *Parinari* sp. at the range of 0.02 Kg/ha to 0.03 Kg/ha. Other species had low contribution to carbon across saplings and seedlings per ha as shown in Fig. 3.

3.4 Saplings and Seedlings Carbon Stock across Species in ADS

Unlike in the in IFS, ADS had low values of carbon stock across species and tree sub-categories. Saplings dominated the seedlings component as presented with species mainly *Berchemia discolor*, *Combretum schumannii*, *Milicia excelsa* and *Sterculia quinqueloba*.

Seedlings carbon stock was mainly contributed by *Brachylaena huillensis*, *Brugueira gymnorhiza*, *Dalbergia melanoxylon* and *Tamarindus indica*. Saplings and seedlings, which contribute largely to carbon stock had a stock ranging between 0.36 Kg/ha to 0.58 Kg/ha, while less values of carbon were recorded in other species as shown in Fig. 4.

3.5 Saplings and Seedlings Carbon Stock across Species in LDS

The trend of carbon stock in LDS differed across the species and tree categories. The stock of carbon was significantly contributed by saplings such as *Afzelia quanzensis*, *Dialium holtzii* and *Diospyros abyssinica* and *Tamarindus indica*. Seedlings carbon values were dominated by *Baphia* sp., *Brachylaena huillensis*, *Pericopsis angolensis* and *Tamarindus indica*. These species had values ranging between 0.50 Kg/ha and 0.93 Kg/ha. Other species had the mean carbon stock below 0.6 Kg/ ha as shown in Fig. 5.


1.*Tamarindus indica*


2.*Afzelia quanzensis*


3. *Dialium holtzii*


4. *Diospyros abyssinica*


5.*Albizia versicolor*


6.*Tectona* sp.

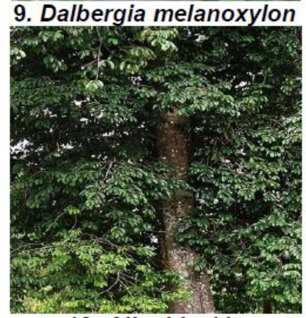

7. *Albizia gummifera*


8. *Julbernardia globiflora*


9. *Dalbergia melanoxylon*


10.*Terminalia sambesiaca*


11. *Milicia excelsa*


12. *Allanblackia stuhlmannii*


13. *Khaya anthotheca*


14.*Terminalia superba*


15.*Sterculia quinqueloba*


16.*Artocarpus heterophyllus*


17. *Baphia* sp.


18.*Xeroderris stuhlmannii*

19. *Brachylaena huillensis*
20. *Combretum schumannii*
21. *Berchemia discolor*
22. *Brugueira gymnorrhiza*
23. *Pericopsis angolensis*
24. *Combretum zeyheri*
25. *Brachystegia boehmii*
26. *Brachystegia spiciformis*
27. *Vangueria* sp.
28. *Pterocarpus* sp.
29. *Parinary* sp
30. *Ficus* sp.
31. *Newtonia buchananii*
32. *Ocotea* sp.
33. *Sterculia appendiculata*

Fig. 2. Tree species photographs

3.6 Adult Trees Carbon Stock across Species in IFS

Carbon stock in adult trees was higher in *Tamarindus indica*, *Allanblackia stuhlmannii*, *Baphia* sp. and *Parinari* sp. The carbon stock in these species ranged between 200 Kg/ha to 3000 Kg/ha. The lowest stock was in *Terminalia sambesiaca*, *Milicia excelsa*, *Berchemia discolor*, *Brugueira gymnorhiza, Brachystegi aboehmii* and *Vangueria* sp. with the stock value below 200 Kg/ha as shown in Fig. 6.

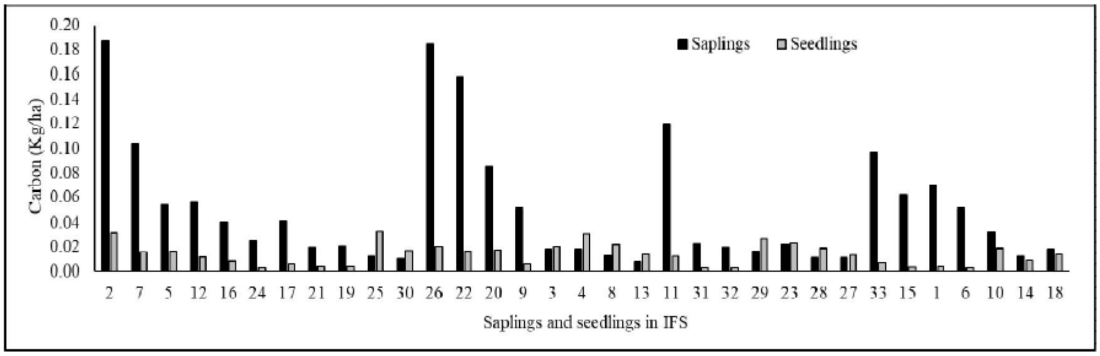


Fig. 3. Saplings and seedlings carbon stock in IFS

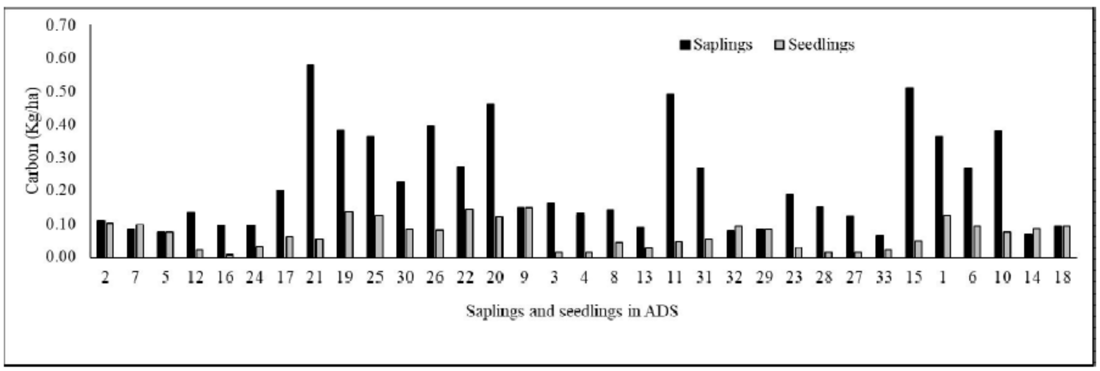


Fig. 4. Saplings and seedlings carbon stock in ADS

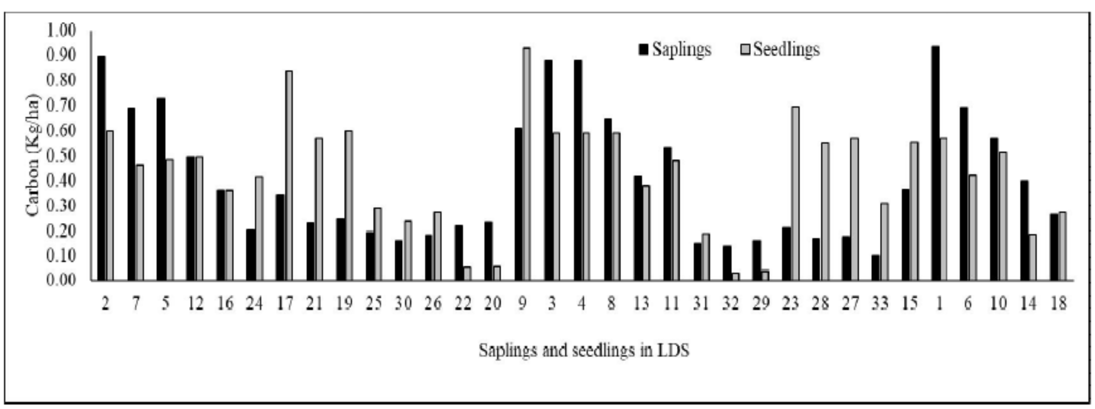


Fig. 5. Saplings and seedlings carbon stock in LDS

3.7 Adult Trees Carbon Stock across Species in ADS

In ADS, the highest carbon stock was recorded in *Tamarindus indica*, *Artocarpus heterophyllus*, *Baphia* sp. and *Parinari* sp. These species had carbon values between 200 Kg/ha and 1500 Kg/ha.

The lowest values were recorded in *Brugueira gymnorhiza* and *Vangueria* sp. with the carbon stock of less than 200 Kg/ha (Fig. 7).

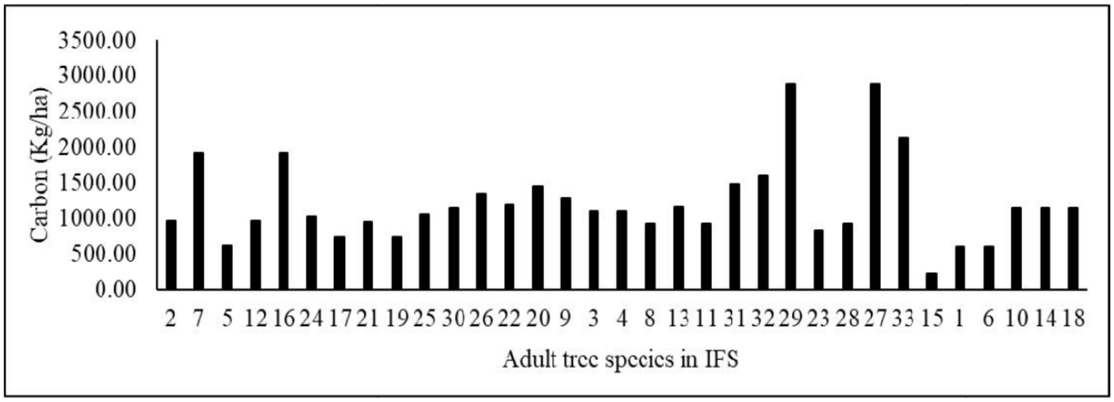


Fig. 6. Adult trees carbon stock in IFS

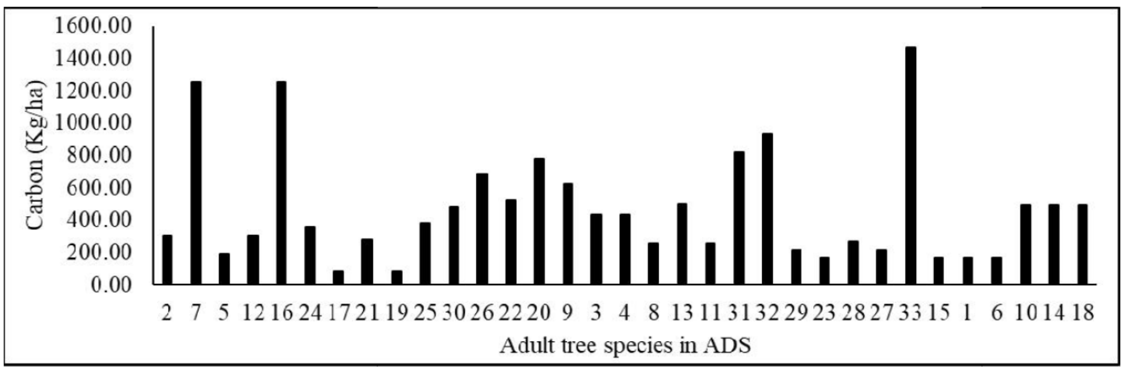


Fig. 7. Adult trees carbon stock in ADS

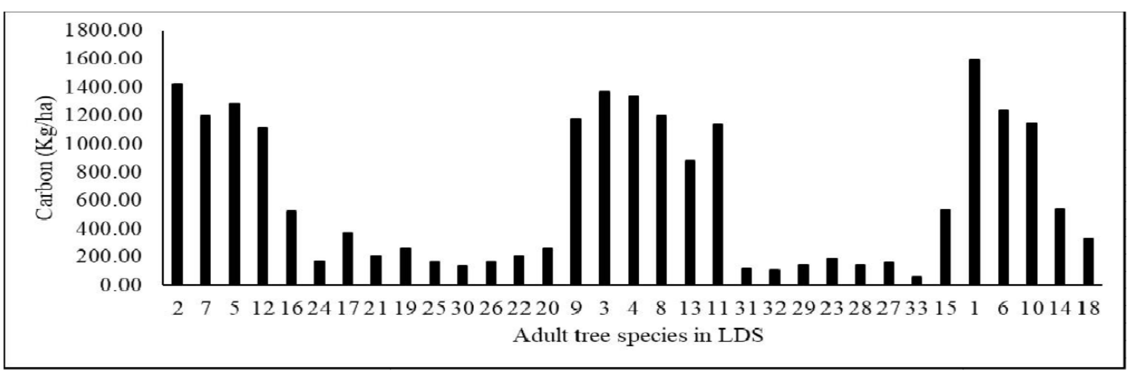


Fig. 8. Adult trees carbon stock in LDS

3.8 Adult Trees Carbon Stock across Species in LDS

In LDS, the highest stock of carbon was in *Tamarindus indica*, *Dialium holtzii*, *Artocarpus heterophyllus*, *Baphia* sp. and *Parinari* sp. with carbon stock between 200 Kg/ha to 1500 Kg/ha. The lowest carbon stock was recorded in *Berchemia discolor*, *Brugueiragy mnorhiza* and *Vangueria* sp. each with carbon below 200 Kg/ha (Fig. 8).

4. COMPARISON OF CARBON STOCK ACROSS LAND USES

4.1 Carbon Storage across Land Uses

This work show some variation of carbon stock across intact forest, crop-agriculture and livestock disturbed sites (Figs. 1-8). This variation shows that human activities (crop-agriculture and livestock grazing) affect forest structure. In turn, these activities affect the potential of trees to function as carbon sink and store on particular land uses. It indicates that different management of different land uses and disturbances affect carbon storage in the vegetation component of forests ecosystems [59]. Carbon stock in the regenerating species indicates that disturbances affect vegetation, but after some restoration measures such as exclusion of crop-agriculture and livestock grazing, there are some potential values to rejuvenate forests and restore the capacity of these ecosystems to store biomass carbon as supported by [44]. The potential to function as carbon stocks is mainly based on the capacity of the land use to permit regeneration and growth of trees. The variation of carbon stored in a particular land use shows that it is not only the density of species that determines carbon amount, but the capacity of species to store carbon, which differs from one species to another as determined by many factors such as heights, agreeing to the findings in [18]. The variation of carbon storage across trees sub-categories was expected in this study because trees categories differ in heights and diameters, and these factors hold important implications for carbon storage potential in tropical forests [63]. The computed carbon stock across the study sites indicates that coastal forests play important role in ecosystems services such as carbon storage [43], but different land management affect the tree growth parameters and carbon storage potential.

4.2 Carbon Stock between Intact and Disturbed Sites

Across different land uses, it is indicated that there is less carbon in crop-agriculture regenerating species agreeing with [47]. The intact forest sites had higher carbon stock than crop-agriculture and livestock disturbed grazing sites. The higher amount of carbon in intact forest sites indicates that protection or allowing natural regeneration to take place contributes to the store above ground carbon stocks [18]. The higher carbon stock in intact forest sites is within the average range reported for adult trees in [9,64,65]. Low carbon stock in crop-agriculture and livestock grazed sites, shows that disturbances affect the regeneration of trees, and hence there is low carbon storage in the tropics supporting [66] findings. Low carbon in disturbed sites is a result of the low density of adult trees. Interestingly, disturbed sites had carbon potential in saplings and seedlings, which equally compares to the average quantity of carbon stocks in bushland and grasslands of the tropics [56,57].

4.3 Carbon Stock within the Disturbed Sites

The amount of carbon in the regenerating species of the livestock grazed sites differed slightly from that on crop-agriculture sites. Although both livestock grazing and crop-agriculture are associated with vegetation disturbances in forest ecosystems; these activities affect the aboveground forest biomass and carbon stocks differently [23,66,67]. From the study sites, it is obvious that the impacts of livestock grazing are somehow less than those caused by crop-production because livestock grazing is selective and leaves some species unaffected, unlike crop-agriculture. Indeed, the amount of carbon recorded within these two land uses shows that these lands have the potential to regenerate forest trees, contributing to the conservation of trees within the previously disturbed sites, in turn improving the storage of carbon [39,37]. The carbon stored in the regenerating tree species is a sign that coastal forests have a high capacity of resilience of carbon stocks that are can be enhanced through conservation and restoration [68].

4.4 Carbon Stock across Tree Sub-categories

The general trend showed a substantial increase in carbon stock across tree sub-categories and land uses. Carbon stock was less in seedlings but higher in saplings and adult trees across the land uses. The variation of carbon stock across tree sub-categories indicates that as trees grow accumulates higher carbon than the regenerating seedlings and saplings. This view supports the observations in [48]. Carbon variation across seedlings, saplings, and adult trees show that the regenerating seedlings and saplings play a carbon storage function, not like the role played by mature and old-growth natural forests [69]. The estimated quantity of carbon in the seedlings and saplings confirms the potential of tropical forests to regenerate and store carbon after conservation measures [37]. Carbon storage in seedlings and saplings shows that the young forests constitute carbon storage of coastal forests like many other tropical forests [69]. The low variation of carbon in seedlings and saplings (regenerating trees) shows that carbon pools and regenerating species have different recovery rates [70,71]. The carbon in disturbed sites shows that disturbance lowers carbon content in the ecosystems, and it might take a long time for the disturbed sites to rejuvenate and gain higher levels above-ground biomass and carbon stock potential [71,72]. Specifically, this variation shows the contribution of the regenerating tropical forests located in the coastal zone in reducing CO2 in the atmosphere. The low variation of carbon in seedlings and saplings across the land-use sites suggests that degraded forests and abandoned agricultural lands have the potential to recover as well as play the role of carbon and biodiversity values if they are left to regenerate naturally [72].

4.5 Carbon Stock across Different Species

The variation of carbon stock across different species in this study shows that different plant species have different capacities to sequestrate carbon during photosynthesis supporting the findings in [32]. Although in this study the author has used the generalized allometric equations to quantify carbon stock for all the thirty-three species, interestingly, the computed values of carbon in our study area are within that reported in other studies like [9,25,73,65], but they are contrary to the values reported in [32]. These contradicting findings might result from variation of species, location, and age of the tree and methods of quantifying carbon stocks [32]. It is possible that the variation, which is between our work and the existing literature, would have been counterbalanced if the author had used the destructive methods of carbon assessment across the species. However, the variation established across the study sites and tree species suggest that farming and livestock grazing have impacts on forest carbon stocking [9,66]. In this study, it shows that exclusion of human activities in the tropical coastal forests facilitates natural regeneration, and thus improving carbon stocking. Therefore, the regenerating species play an important role in carbon storage like many other natural forests agreeing to the documentation in [74].

4.6 Carbon Stock and Its Implications on Climate Change

The interplay between forest disturbances, regeneration, carbon sources or stocking and climate change is complex because climate change is both a cause and an effect of forest change [74,75]. The quantified carbon stock across land uses and tree sub-categories are important in understanding the role of regenerating forests in addressing climate change mitigation [76]. Our findings show lower carbon stock per unit area agreeing with the findings in [57] but contrary to [77,78,79]. This controversy shows that forest disturbance in Tanzania is high and continues to be a challenge in addressing global efforts to mitigate climate change [57,79]. Lower carbon stock in the disturbed sites implies that disturbances affect the potential of forests to store carbon. However, these findings highlight that there is some carbon stocking potential in some of the regenerating trees for carbon sequestration and climate change mitigation. Therefore, converting the disturbed sites into forests may increase carbon sequestration as some tree species have a good capacity to regenerate and play the crucial role of carbon storage, a function, which is important in addressing climate change after disturbances.

5. CONCLUSION

This study confirmed the hypothesis that carbon storage differs between regenerating species of the intact forest sites from crop-agriculture and livestock disturbed sites. The study concludes that there are significant variations of carbon stock values across the thirty-three species, tree-sub-categories and the average amount of carbon across the three land uses. These carbon stock variations are useful indicators that different land use management affects the potential of coastal forests to function as carbon sinks in addressing changing climate mitigations. Indeed, the higher quantities of carbon in adult trees of the intact forest sites than those found in the disturbed sites provide a piece of useful information that disturbances that cause loss of forest trees results in forests to act as carbon sources rather than sinks. Therefore, it is important to promote restoration, protection, and conservation of forest species to optimize carbon stocking benefits for sustainable management of coastal forest ecosystems.

COMPETING INTERESTS

The author has declared that no competing interests exist.

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