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# Ecological economics of cashew trees (*Anacardium occidentale)* in eastern corridor of selous-niassa trans frontier conservation area, Tanzania and Mozambique

**Adili Y Zella[1], Mdee Norah V[2]**
[1] Department of Economic Studies, the Mwalimu Nyerere Memorial Academy, Dar es Salaam, Tanzania
[2] Tanzania Wildlife Research Institute, Mahale/Gombe Research Centre, Kigoma, Tanzania

**Abstract**
Climate is changing and that the changes are largely due to increased levels of carbon emissions into the atmosphere caused by changes of land uses as a result of anthropogenic activities. Considering the impacts of climate change insisted the need for new conservation areas to fill connectivity gap between protected areas (PAs) or transfrontier conservation areas (TFCAs) through habitat corridors so as to enable species migration with their climatic niche. However depending on conservation criterion sometimes these corridors resides with dwellers who depend on corridor resources for their livelihood. Selous – Niassa TFCA is one among the TFCAs connected with corridor which corridor dwellers depend it for their livelihood. The corridor is rich with cashew trees (*Anacardium occidentale)* which is the principle cash crop in the area. Cashew trees like many other Trees outside Forests (TOF) have important economic, social and environmental values, at local, national and international scales. Environmental benefits of carbon sequestration of cashew trees is of important to corridor dwellers as it add value in poverty alleviation through carbon market schemes like REDD+. This study aim to estimate amount of biomass and carbon stock of cashew trees in eastern Selous – Niassa TFCA and its contribution to income generation through carbon market. Archive data was analysed to get the intended output. Results indicates coconut trees to have biomass stocks of 2, 417, 853.06 tonnes equivalent to 1, 136, 201.22 tonnes of carbon stocks and producing accrued profit amounted US$ 4, 544, 804.88 if adapted REDD+ programmes. The study concludes that cashew trees have both ecological and socio-economic benefits. It is suggested that, production, productivity and sustainable utilisation of cashew trees should be emphasized to safeguard reliance of corridor natural resources for livelihoods.

**Keywords:** climate change, forest sequestration, cashew trees, carbon market

## 1. Introduction

### 1.1 Background Information

Climate is changing and that the changes are largely due to increased levels of carbon emissions into the atmosphere caused by changes of land uses as a result of anthropogenic activities (IPCC, 2013; UNFCCC, 2010 & 2009) [6]. Considering the impacts of climate change insisted the need for new conservation areas to fill connectivity gap between protected areas (PAs) or transfrontier conservation areas (TFCAs) through habitat corridors so as to enable species migration with their climatic niche. However depending on conservation criterion sometimes these corridors reside with dwellers who depend on corridor resources for their livelihood. Selous – Niassa TFCA is one among the TFCAs connected with corridor where corridor dwellers depend for their livelihood. The area is rich in valuable natural miombo trees and other trees species planted as food or cash crops.

Trees act as a sink for carbon dioxide by fixing carbon during photosynthesis and storing excess carbon as biomass. The net long term carbon dioxide source or sink dynamics of forest change through time as tree grow, die and decay. Additionally, human influences on forest can further affect carbon dioxide source or sink dynamics of forest through such factors as fossil fuel emission and utilization of biomass (Soberg *et al.*, 2015). The rate of carbon storage increases in young stands, but they decline with the passage of time as the ages of the stands increase. Increased levels of $CO_2$ in the atmosphere caused by human beings necessitate the compensation for the additional anthropogenic carbon. Existing urban, semi-urban and rural forests are unable to balance carbon cycle created by industrialization and urbanization (Soberg *et al*., 2015). Additional environmental and economic benefits can be attained through increasing the forest canopy and trees lifespan. Planted trees as cash crops like cashew (*Anacardium occidentale*) trees plays a significant role in climate change mitigation by sequencer carbon from the atmosphere.

Cashew (*Anacardium occidentale*) tree is a tropical nut crop brought to East Africa and India by the Portuguese in the sixteenth century (Johnson, 1973; Ohler, 1979; Behrens, 1998) [14, 3]. It consists of about 73 genera and 600 species (Nakosone and Paull, 1998) [11]. The tree is evergreen, fast growing and it reaches a height of 10-15m tall, often irregularly shaped trunk (UNIDO, 2011) [22]. Cashew trees are planted in plantations of around 70 trees per hectare at a spacing of 12m X 12m (NARI, 2009; UNIDO, 2011) [12, 22]. It grows well from sea level up to 1200 m above sea level (a.s.l) where the temperature does not fall below 20ºC. The optimum monthly temperature for cashew growth is $24^0$C to 28ºC. Cashew is grown in areas with rainfall ranging from 800 – 1600 mm per annum, and the soil pH ranging from 4.5 to 6.5. Cashew trees are well adapted to Tanzania and planted by majority smallholder farmers. It has ability to grow on poor soils and can be intercropped with food crops (maize, cassava, groundnuts etc). Cashew farm management practices consist of weeding, pruning and spraying pesticides and fungicides (NARI, 2009; UNIDO, 2011) [12, 22]. The crop is best adopted to the Southern region of Tanzania (Mtwara, Lindi and Ruvuma), Coast, Dar es salaam, and Tanga regions (Shomari, 2000; NARI, 2009; Orwa *et al.*, 2009, Masawe *et al*., 2013) [18, 12, 12, 15, 10].

Cashew (*Anacardium occidentale*) trees like many other Trees outside Forests (TOF) have important economic, social and environmental values, at local, national and international scales. The products from cashew trees that are traded on international market and give foreign earnings to the nation economy as well as to the farmers are raw nuts, cashew kernel and Cashew nut shell liquid oil (CNSL) while cashew apple are consumed locally in Tanzania (World Bank, 1989; UNIDO, 2011; Mlagalila, 2016) [22, 5]. Cashew apples can be processed into juice, fresh and dried fruit, jams, wines, candies and animal feed made out of waste products of cashew apple (UNIDO, 2011; Masawe *et al*., 2013; Pinho *et al*., 2010; Mlagalila, 2016) [22, 10, 15, 17]. Furthermore, cashew trees can add income to smallholder famers through carbon market by adapting REDD+ (Reducing Emissions from Deforestation and forest Degradation and the role of conservation, sustainable management of forests and enhancement of carbon stocks) strategies.

Quantifying cashew trees biomass and volume may be important for several reasons. Quantification of amounts of biomass, and subsequently C, is presently an important component in the REDD+ initiative. REDD+ is a system of financing mechanisms and incentives aiming at mitigating climate change by reducing deforestation and forest degradation. Participating countries in REDD+ projects are required to produce accurate estimates for their forest C stocks and changes through robust Measurement, Reporting and Verification (MRV) schemes. The assessment of REDD+ is done by comparing current rate of deforestation and forest degradation against established historical rate known as Reference Emission Level (REL)/Reference Levels (RL). The estimation of REL or RL utilises biomass models. Quantification of biomass is also essential for issues related to energy production (fuelwood and charcoal production) in conventional forest and trees species management planning (Malimbwi *et al.*, 2018, Angelsen *et al*., 2012 & 2011) [9, 2].

### 1.2 Problem Statement

Tanzania has completed her National Forest Inventory (NFI) popularly known as NAFORMA (URT, 2015). The major tree variables measured were diameter at breast height (dbh) and total tree height (ht). Using appropriate biomass and volume models, these variables have been used to estimate single tree biomass and volume. The single tree biomass and volume estimates are usually further projected to stand average values in terms of biomass or volume per ha for different biomes. Knowing the extent of the biomes in ha, the total biomass or volume of each biome can be estimated and aggregated into district, regional and finally national estimates. The stand volume estimates are the basis for forest and trees species management purposes such as assessment of growing stock, timber valuation, selection of forest areas for harvests, for growth and yield studies and hence achieving sustainable forest and trees species management. The biomass is further converted into C and $CO_2$ and hence enabling the estimation of REDD+.

However, cashew trees have potential to sequester atmospheric carbon dioxide and therefore qualify for carbon trading mechanisms such as REDD+. Yet, this opportunity still unexploited to smallholder farmers of cashew trees residing in eastern corridor of Selous-Niassa TFCA. The present paper is an attempt to evaluate the contribution of cashew (*Anacardium occidentale)* trees in biomass and carbon store and its role in increasing income of small scale farmers in eastern corridor of Selous-Niassa TFCA through carbon market.

### 1.3 Objectives

#### 1.3.1 Main objective

The overall objective of this study was to evaluate amount of biomass and carbon stock of cashew (*Anacardium occidentale)* trees in eastern corridor of Selous-Niassa TFCA

#### 1.3.2 Specific objectives

Specifically the study intends to:

1. estimate amount of biomass stock of cashew trees in eastern corridor of Selous-Niassa TFCA
2. estimate amount of carbon stock of cashew trees eastern corridor of Selous-Niassa TFCA
3. estimate amount of profit to be accrued from carbon market of cashew trees eastern corridor of Selous-Niassa TFCA

## 2. Materials and methods

### 2.1 Materials

#### 2.1.1 Description of the Study Area

The study was carried out in eastern Selous-Niassa TFCA with an area of 1, 462, 560 hectares called Selous-Niassa wildlife corridor (SNWC) which extends across southern Tanzania into northern Mozambique between $10^0$S to $11^0$ 40'S with north-south length of 160 to 180 km (Figure 1). SNWC comprises of two parts, western part (administratively passes in Namtumbo and Tunduru Districts of Ruvuma regions in southern Tanzania) and eastern part (administratively passes in Liwale, Nachingwea, Masasi, and Nanyumbu Districts). This study concentrated in eastern part. In eastern SNWC, migration of elephants, buffalos and zebras has been observed (Pesambili, 2003; Ntongani *et al*., 2007) [16, 13]. The study area comprise wildlife management areas (WMAs) bordering Selous, Msanjesi and Lukwika-Lumesule game reserves (MAGINGO WMA, NDONDA and MCHIMALU proposed WMAs respectively) which are within Liwale, Nachingwea/Masasi and Nanyumbu Districts respectively.

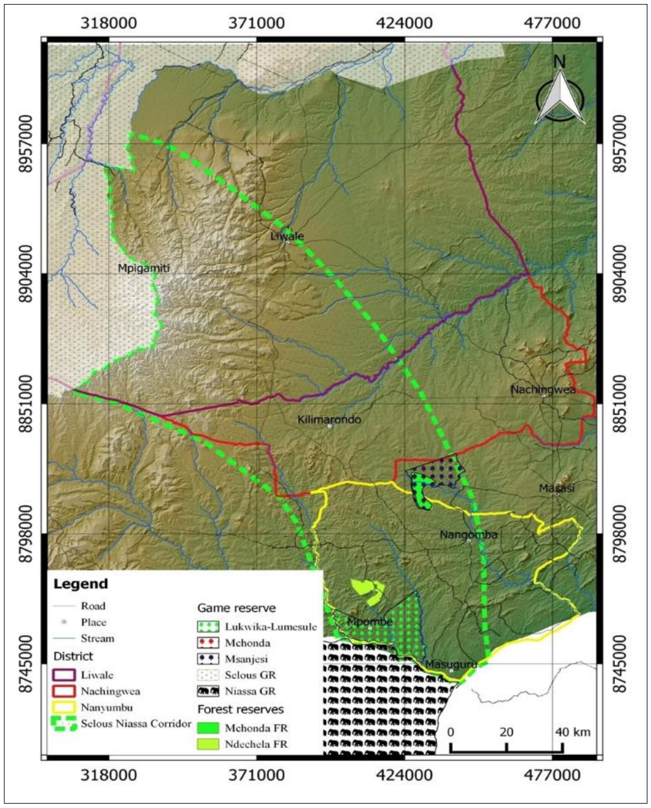


**Fig 1:** The Map of the study area

## 2.2 Methods

Existing archive data on amount of land occupied by cashewnut crops, number of cashewnut trees, and average sizes were used in this study.

### 2.2.1 Data analysis

***To estimate amount of biomass stock of cashewnut trees in eastern corridor of Selous – Niassa TFCA***

Tree biomass was determined as a product of respective component fresh weight and DF-ratio. AGB (Above ground biomass) and BGB (Below ground biomass) were computed by summing the biomass of all above and belowground components respectively). Volume was estimated using formulas developed by Zahabu *et al*. in Malimbwi *et al.* (2018) [9] and Mlagalila (2016) [5].

Allometric models for predicting total AGB and BGB for cashew trees (comprise stems, branches, leaves and twigs). Total volume models were adopted from Zahabu *et al*. in Malimbwi *et al.* (2018) [9] and Mlagalila (2016) [5] as follows:

**Table 1:** Biomass models for cashew trees

| Component | Model |
|---|---|
| AGB | $B = 0.8450 \times (dbh^2)\ 0^{.8873}$ |
| BGB | $B = 0.09287 \times (dbh^2)^{0.9394}$ |
| Stem-branches | $B = 0.0951 \times dbh^{2.2622}$ |

B = biomass (kg), dbh = diameter at breast height (cm)

**Table 2:** Volume models for cashew trees

| Component | Model |
|---|---|
| Stem-branches | $V = 0.0000001 \times dbh^{2.6044}$ |

V = volume ($m^3$), dbh = diameter at breast height (cm)

Cashew trees sizes with dbh 1.3 m. For cashew trees, dbh explained a lot of variation in biomass and volume compared with other trees species where height explained much of the variation. According to Mlagalila (2016) [5], eastern corridor of Selous – Niassa TFCA have average biomass estimates for total tree biomass of 34.41± 4.96tC/ha and total carbon stock was estimated to be 16.17±2.33tC/ha as summarized in Table 3.

**Table 3:** Cashew farms mean structure, total volume, biomass, and carbon stocks

| Stocking (N) stems/ha | Basal Area (G) $m^2$/ha | Volume (V) $m^3$/ha | Total Biomass t/ha | Total Carbon t/ha |
|---|---|---|---|---|
| 168 | 5.15 | 48.88 | 34.41 | 16.17 |

**To estimate amount of carbon stock of cashewnut trees in eastern corridor of Selous – Niassa TFCA**

Amount of carbon stock of coconut trees computed following NAFORMA methodology (URT, 2015) as follows:

Carbon (tons/ha) = Biomass x 0.47

According to Mlagalila (2016) [5], eastern corridor of Selous – Niassa TFCA contains average of 50 cashew trees in one hectare (50 trees/ha) therefore average carbon stock per cashew tree can be estimated as follows:

Carbon (tons/coconut tree) = Biomass x 0.0094

**To estimate amount of profit to be accrued from carbon market of cashewnut trees in eastern corridor of Selous – Niassa TFCA**

The estimation calculations adopted Lobora *et al.* (2017) methodology of the standard carbon market is US$ 4 per ton if

REDD+ is implemented. This methodology employed to estimate amount of money that can be accrued by smallholder famers of cashewnut trees in eastern corridor of Selous – Niassa TFCA.

## 3. Results and Discussion

### 3.1 Amount of biomass stock of cashewnut trees in eastern corridor of Selous – Niassa TFCA

Results in Table 4 reveals that, cashewnut trees in eastern corridor of Selous – Niassa TFCA has biomass stock of 2, 417, 853.06 tonnes. Individual coconut tree has an average of 688.2 kg of biomass. This results necessitate strengthen of cashew trees production and productivity due to its contribution in climate change mitigation and socio-economic welfare of smallholder famers of cashew trees.

**Table 4:** Biomass stock of cashewnut trees in eastern corridor of Selous – Niassa TFCA

| Total farm land (ha) | Volume ($m^3$) | Total biomass stock (t) |
|---|---|---|
| 70,266 | 3, 434, 602.08 | 2, 417, 853.06 |

### 3.2 Amount of carbon stock of cashewnut trees in eastern corridor of Selous – Niassa TFCA

The results in Table 5 revealed that cashewnut trees in eastern corridor of Selous – Niassa TFCA have total carbon stock of 1, 136, 201.22 tonnes. Sustainable cropping and utilization of these trees is a climate change mitigation measure. Therefore, it is important to encourage farmers through training on various agronomical practices so as to increase production. Additionally, production factors such as fertilizers and extension service are supposed to be positively encouraging in the as emphasized much by Mlagalila (2016) [5].

**Table 4:** Carbon stock of cashewnut trees in eastern corridor of Selous – Niassa TFCA

| Total farm land (ha) | Volume ($m^3$) | Total carbon stock (t) |
|---|---|---|
| 70,266 | 3, 434, 602.08 | 1, 136, 201,22 |

### 3.3 Amount of profit to be accrued from carbon market of cashewnut trees in eastern corridor of Selous – Niassa TFCA

Table 6 indicates average amount of money which should be accrued through carbon market by smallholder famers of cashew trees in eastern corridor of Selous-Niassa TFCA if adopted REDD+ strategy. The average accrued amount of money for individual cashew tree in carbon market is US$ 2.29 (TZS 2, 978.28). This results emphasize improvement in production and productivity of cashew trees so that the accrued benefits can offset production cost resulting to improvement of livelihoods of eastern corridor of Selous-Niassa TFCA.

**Table 6:** Accrued profit of cashewnut trees in eastern corridor of Selous – Niassa TFCA

| Total farm land (ha) | Total carbon stock (t) | Total carbon stock (US$) |
|---|---|---|
| 70,266 | 1, 136, 201 | 4, 544, 804.88 |

## 4. Conclusion and Recommendations

### 4.1 Conclusion

This study estimated amount of biomass and carbon stocks of cashew (*Anacardium occidentale*) trees in coastal areas of Tanzania. The findings have revealed that there are 2, 417, 853.06 tonnes of biomass equivalent to 1, 136, 201.22 tonnes of carbon stocks in cashew trees of eastern corridor of Selous-Niassa TFCA. Furthermore, the carbon market can produce average total amount of US$ 4,544,804.88. Therefore strengthening cashew trees production and productivity add extra environmental and socio-economic values as climate change mitigation strategy and income generating activity through carbon trade if adapted REDD+ programme. These will reduce encroachment of corridor habitat and allow mobility of wildlife species in different patches for adaptation purposes due climate change in core protected areas or migration while maintaining ecological, biological and ecosystem parameters.

### 4.2 Recommendations

The study provides the following recommendations for sustainable production, productivity, and utilization of cashew (*Anacardium occidentale*) trees in eastern corridor of Selous-Niassa TFCA:

- The government and smallholder farmers of cashew trees should include these tree species into REDD+ scheme
- The government should provide fund for more scientific research on cashew trees production and productivity
- The government with cashew trees farmers should rehabilitate all old trees, apply fertilizers, weeding, and pest management
- The government should provide extension services to cashew trees farmers so that the benefits can offset production cost.
- The government should negotiate with local, regional and international organizations on adding the price of carbon per ton so as to stimulate trees production and sustainability of carbon sequestration.

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