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Contribution of coconut trees (*Cocos nucifera)* in biomass and carbon store and its' role in improving livelihood of small scale farmers of coastal areas of Tanzania

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ABSTRACT
Global warming and climate change are growing environmental concerns that are resulting from the accumulation of greenhouse gases such as carbon dioxide (CO_2) in the atmosphere as a result of human anthropogenic activities. The CO_2 concentration in atmosphere increased from 280 ppm at the beginning of the industrial revolution to 368 ppm by the year 2000 and is projected to increase to 540 ppm by 2100. Land-use change and deforestation is responsible for about 25% of all greenhouse emissions. As international agreements over greenhouse gas emissions and global warming are negotiated, there is growing interest in the possibility of reducing the increase in the amount of CO_2 in the atmosphere through forest-based carbon sequestration project.

Forests sequester and store more carbon than any other terrestrial ecosystem and are important climate change mitigation. Carbon sequestration has been globally emerged as a potential profitable business, which is oriented to socioeconomic development and environmental amelioration. However in East Africa including Tanzania, this carbon sequestration business considered some categories of forests, trees farming and trees species. There is a growing concern of some homestead forestry which grown for food and income purposes but have variety of outputs that have both production and service values including aesthetic and ecological benefits. This study concentrates on contribution of coconut trees (*Cocos nucifera)* in biomass and carbon store and its role in improving livelihood of small scale farmers in coastal areas of Tanzania through carbon market. Archive data was analysed to get the intended output. Results indicates coconut trees to have biomass stocks of 10, 818, 072.1 tons and 2, 466, 520.5 tons equivalent to 101, 689.9 tons and 23, 185.29 tons of carbon stocks producing accrued profit amounted amount of US$ 406, 759.5 and US$ 92, 741.17 if adapted REDD+ strategies in coastal areas of mainland Tanzania and Zanzibar islands respectively. The study concludes that coconut trees have both ecological and socio-economic benefits. It is suggested that, production, productivity and sustainable utilisation of coconut trees should be emphasized.

Keywords: Climate change; Forest sequestration; Coconut trees (*Cocos nucifera);* Carbon market

1. INTRODUCTION

Background Information

Global warming and climate change are growing environmental concerns that are resulting from the accumulation of greenhouse gases such as carbon dioxide (CO_2) in the atmosphere. There is strong evidence that human activities have affected the world's climate (IPCC, 2000). Deforestation and burning of forests releases CO_2 to the atmosphere. The CO_2 concentration in atmosphere increased from 280 ppm at the beginning of the industrial revolution to 368 ppm by the year 2000 and is projected to increase to 540 ppm by 2100 (Watson, 2000). Conversely, land-use change and forestry is responsible for about 25% of all greenhouse emissions. Moreover, deforestation and forest degradation in the tropics contribute significant emission of CO_2 as among of anthropogenic greenhouse gas (GHG). Anthropogenic carbon emissions contribute 10% of GHG (IPCC, 2013). As international agreements over greenhouse gas emissions and global warming are negotiated, there is growing interest in the possibility of reducing the increase in the amount of CO_2 in the atmosphere through forest-based carbon sequestration projects (REDD+ (Reducing Emissions from Deforestation and forest Degradation, forest conservation, sustainable management of forests, and enhancement of forest carbon stocks) in developing countries. However, previous studies on REDD+ have shown that community members can reliably and cost-effectively monitor forest biomass. At the same time, this can improve local ownership and forge important links between monitoring activities and local decision-making. Existing studies on REDD+ have, however, been static assessments of biomass at one point in time. REDD+ programs requires repeated surveys of biomass over extended time frames.

REDD+ initiated as an international mitigation mechanism under the United Nations Framework Convention for Climate Change (UNFCCC) (UNFCCC, 2009). REDD+ offers a performance based financial incentive for participating developing countries, i.e. a payment per ton of CO_2 from reduced carbon losses as compared to a reference emission level (REL). Countries participating in REDD+ need to establish a Measuring, Reporting and Verification (MRV) system for changes in forest carbon pools and related greenhouse gas (GHG) emission (UNFCCC, 2009). The REL is defined either as a historic baseline from past deforestation data, or as a modeled projection of such data (UNFCCC, 2010; Angelsen, 2011). The forest carbon pools addressed include Above-Ground Biomass (AGB); Below-Ground Biomass (BGB); deadwood; litter and soil organic matter (Angelsen, 2012). As MRV methods developed, AGB plays a key role, as it represents the most easily measurable carbon stock, it can be recalculated to carbon data, and it is a major predictor variable for modelling the other four categories (Solberg *et al.*, 2015). However, individual trees species are not so much considered in REDD+ projects.

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 (Nowak & Crane, 2002; 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.

Additionally, success practices of CC mitigation are increases of the amount of carbon stored in trees of community forests through maintenance of existing forest, and tree plantings in all available planting spaces. Furthermore, examine the species and age composition of the community forest, then choose to plant larger and longer living tree species to maximize the ability to store carbon over time (Soberg *et al*., 2015). Consequently, unproductive land in urban, semi-urban and rural areas, planted with trees and converted into new green space, can then function as a sink for atmospheric carbon dioxide. Existing forested or natural areas should be preserved in order to retain the capacity to store carbon in the soil, since removal results in the release of almost all existing below-ground carbon stores (Soberg *et al*., 2015). Vitally, homestead forestry grown on food and income purposes should be sustainably utilized by considering their aesthetic and ecological benefits on carbon sequestration. Coconut (*Cocos nucifera*) trees are among of the tropics homestead forestry of high economic and environmental importance. It provides cash income to stallholder farmers through fruits, fronds and wood and basic necessities of life such as food, drink, fuel and shelter. Coconut fruit is the most nutritious healthy drink from palm tree, is a natural isotonic drink that has content similar to our body's blood plasma (Fife, 2008). Healthy benefits of coconut includes natural isotonic drinks, prevents oxidative stress, antioxidant activity, lipid peroxidation activity, improve lipid profile, improve blood pressure, cardio protective activity, anti-inflammatory effects, diarrhea therapy, antidiabetic activities, and increase hemoglobin levels (Zulaikhah, 2019 Fife, 2008).

Coconut (*Cocos nucifera*) tree is one of the four major palm species of economic importance among nearly 2400 palm species in the world. The other three are *Elaeis oleifera, Borassus flabellifer* and *Phoenix dactylifera* (Arancon, 1997; Govaerts and Dransfield, 2005; Goodman *et al*., 2013; Malimbwi *et al*., 2018). A lager majority of coconut trees are found in higher rainfall coastal areas characterised by saline soils (Kant, 2010). In Tanzania mainland, coconut trees are dominantly found in regions located in the eastern coast and quite a few in patches in non-coastal regions like Morogoro, Manyara and Tabora (Mwinjaka et al., 1999). In Zanzibar, coconut trees are the most dominant tree species (Revolutionary Government of Zanzibar, 2013).

Problem Statement

Carbon sequestration has been globally emerged as a potential profitable business, which is oriented to socioeconomic development and environmental amelioration. However in East Africa including Tanzania this carbon sequestration business considered some categories of forests, trees farming and trees species. There is a growing concern of some homestead forestry which grown for food and income purposes but have variety of outputs that have both production and service values including aesthetic and ecological benefits. Coconut (*Cocos nucifera*) trees are not exempted from these scenarios; as one of the important tropical crops grown in saline lands and popularly known as 'tree of life' because every part of the species has its own respective use. A merit to farmers is that, there are few other woody vegetation types grow in coastal saline lands resembles coconut trees.

However, coconut trees have potential to sequester atmospheric carbon dioxide and therefore qualify for carbon trading mechanisms such as REDD+ (Reducing Emissions from Deforestation and forest Degradation and the role of conservation, sustainable management of forests and enhancement of carbon stocks). Yet, this opportunity still unexploited to small holder farmers of coconut residing in coastal saline lands. The present paper is an attempt to evaluate the contribution of coconut (*Cocos nucifera)* trees in biomass and carbon store and its role in improving livelihood of small scale farmers in coastal areas of Tanzania through carbon market.

Objectives

Main objective

The main objective of this study was to evaluate amount of biomass and carbon stock of coconut (*Cocos nucifera)* trees and their contribution in improving livelihood of small scale farmers in coastal areas of Tanzania through carbon market.

Specific objectives

Specifically the study intends to:

a. estimate amount of biomass stock of coconut trees in coastal areas of Tanzania
b. estimate amount of carbon stock of coconut trees in coastal areas of Tanzania
c. estimate amount of profit to be accrued from carbon market of coconut trees in coastal areas of Tanzania

2. MATERIALS AND METHODS

Materials

Description of the Study Area

The study was carried out in coastal areas of Tanzania comprises of Mtwara, Lindi, Dar es Salaam, Coast and Tanga regions in mainland Tanzania; and Unguja and Pemba islands in Zanzibar lying between latitude 10 and 12^{0} South and longitude 30^{0} and 40^{0} East (figure 1). The coastal areas of Tanzania mainland comprises 15% of the country total land (142, 095 sq. km) with 25% of total population (estimated as 14.5 million up to May, 2019 (NBS, 2019)) and Zanzibar has an area of 2650 sq. km. Tanzania mainland is tropical with annual average temperature of 32^{0}C, have a hot season from November – February (25-31^{0}C) and the cold periods from May – August (15-20^{0}C). The annual rainfall is about 1200 mm with a dry period of 7 months. Zanzibar is an archipelago formed by two main islands, Unguja and Pemba, plus several smaller islands. The climate is tropical, hot all year round with total annual rainfall of about 1,600 mm in Unguja and 1,900 mm in Pemba.

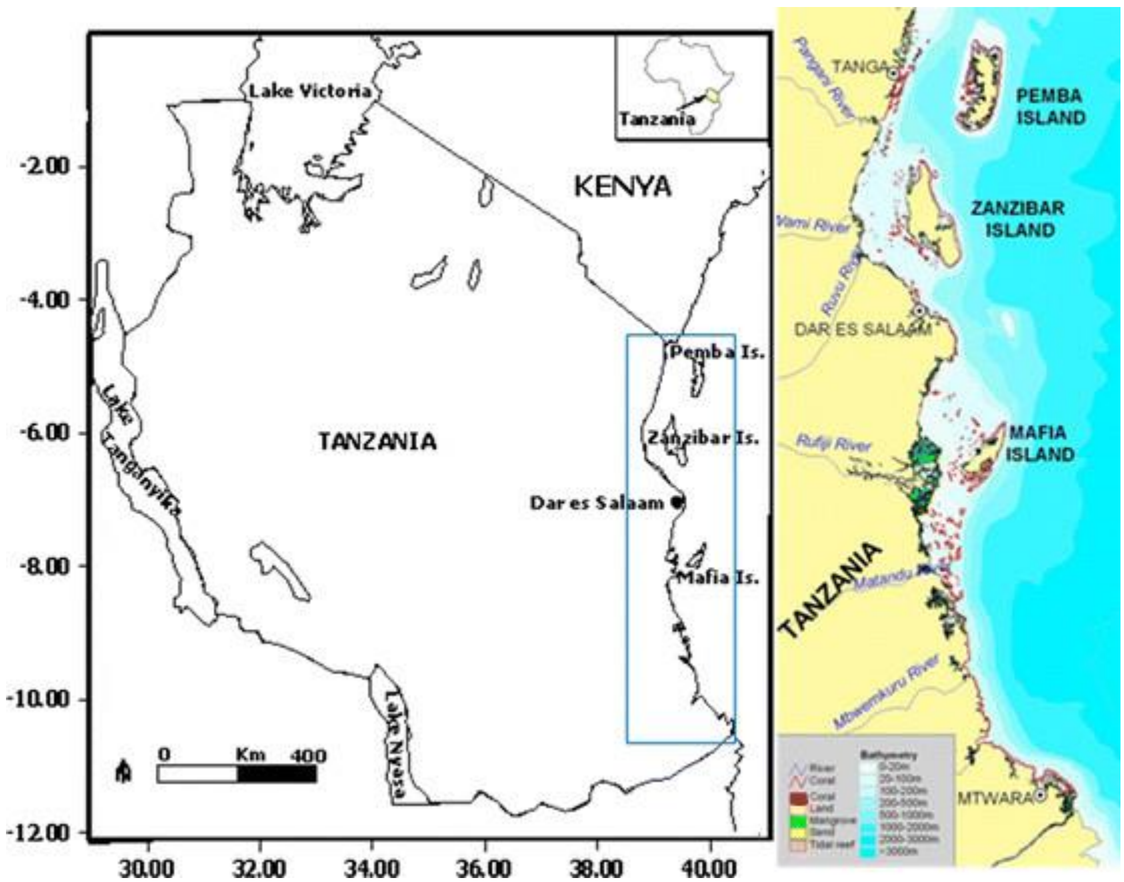

Figure 1 The Map of the study area

Methods

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

Data analysis

To estimate amount of biomass stock of coconut trees in coastal areas of Tanzania

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 (Figure 2). Billet volume was computed by using Huber's formula as explained much by Zahabu *et al*., and Malimbwi *et al.* (2018).

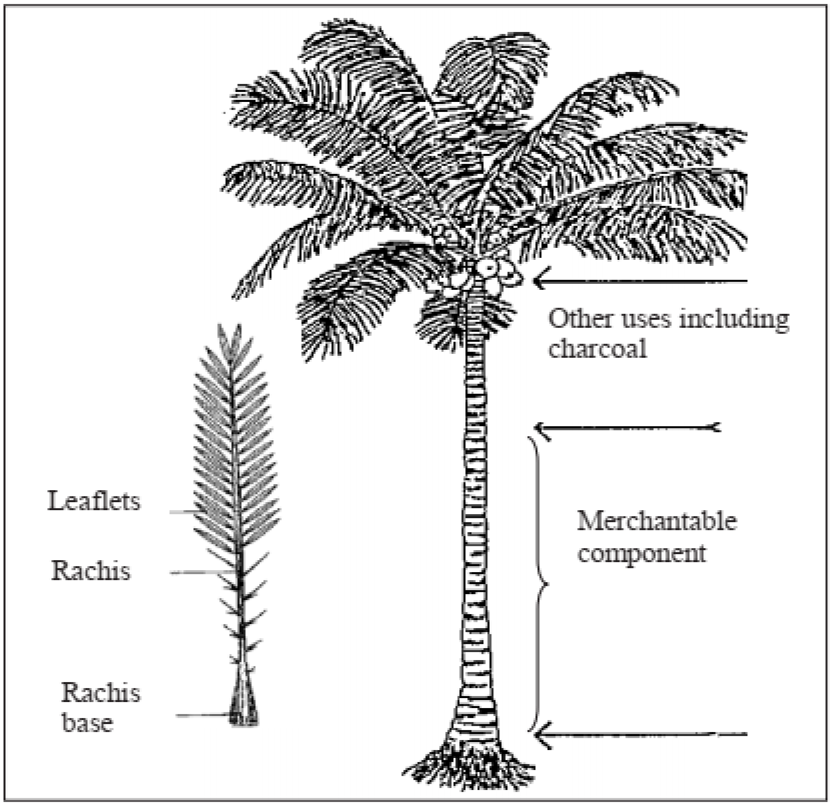

Figure 2 Components of a coconut tree

Allometric models for predicting total AGB, BGB and merchantable stem biomass for coconut trees. Total and merchantable volume models were adopted from Zahabu *et al*. and Malimbwi *et al.* (2018) as follows:

Table 1 Biomass models for coconut trees

Component	Model
AGB	B = 3.7964 x $ht^{1.8130}$
BGB	B = 13.5961 x $ht^{0.6635}$
Merchantable stem	B = 6.0344 x $ht^{1.4191}$

B = biomass (kg), ht = total tree height (m)

Table 2 Volume models for coconut trees

Component	Model
Total	V = 0.0347 x $ht^{1.1873}$
Merchantable stem	V = 0.03043 x $ht^{1.7780}$

V = volume (m^3), ht = total tree height (m)

Coastal areas of Tanzania have coconut trees sizes with average dbh of 19 cm (ranging 19.0 - 40 cm) and ht of 9.5 m (ranging 1.6 - 21 m). For coconut trees, ht explained a lot of variation in biomass and volume compared with dicotyledonous tree species where dbh explained much of the variation (table 1 and 2).

To estimate amount of carbon stock of coconut trees in coastal areas of Tanzania

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

Carbon (tons/ha) = Biomass x 0.47

According to Muyengi *et al.* (2015), coastal land of Tanzania contains average of 50 coconut trees in one hectare (50 trees/ha) therefore carbon stock per coconut 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 coconut trees in coastal areas of Tanzania

The estimation calculations adopted from Jenkins (2014), and Lobora *et al.* (2017) emphasized that, 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 coastal areas of Tanzania.

3. RESULTS AND DISCUSSION

Amount of biomass stock of coconut trees in coastal areas of Tanzania

Results in Table 3 reveals that, coastal areas of mainland Tanzania has biomass stock of 10,818,072.1 tons where by above ground biomass (AGB) contributes 52% followed by merchantable stem (34%) and lastly below ground biomass (BGB) (14%). Table 4 indicates Zanzibar have 2, 466, 520.5 tons of biomass, on which 52% comes from AGB, 14% BGB and 34% merchantable stem. Individual coconut tree has an average of 224.9 kg of biomass. This results necessitate strengthen of coconut trees production and productivity due its contribution in climate change mitigation and socio-economic welfare of smallholder famers of coastal areas of Tanzania. These smallholder farmers practicing coconut trees production in areas of about 0.5 – 1.0 ha covering about 265,000 ha of coastal belt of mainland Tanzania and 61,000 ha of Zanzibar. The total number of coconut palms is estimated as 25 million and 5.7 million palms in coastal areas of mainland Tanzania and Zanzibar respectively; supporting the livelihoods of about 600,000 households (Ngereza, 2013). Zanzibar islands is estimated as, 4.6 million in Unguja and 1.1 million in Pemba. The common coconut varieties grown in Tanzania and Zanzibar islands are East African Tall (EAT) and Pemba Red Dwarf or Pemba Dwarf.

Table 3 Biomass stock of coconut trees in coastal areas of mainland Tanzania

Total number of coconut trees	AGB (t)	BGB (t)	Merchantable stem (t)	Total B stock (t)
25,000,000	5, 622, 440.5	1, 513, 819.1	3, 681, 812.5	10, 818, 072.1

B= Biomass, AGB = above ground biomass, BGB = below ground biomass, t= ton

Table 4 Biomass stock of coconut trees in Zanzibar

Total number of coconut trees	AGB (t)	BGB (t)	Merchantable stem (t)	Total B stock (t)
5,700,000	1, 281, 916.4	345, 150.8	839, 453.3	2, 466, 520.5

B= Biomass, AGB = above ground biomass, BGB = below ground biomass, t= ton

Table 5 & 6 indicates volumes of coconut trees in coastal areas of mainland Tanzania and Zanzibar respectively. Coconut trees found to have 23.2% and 76.8% of volumes in AGB &BGB and merchantable stem for both coastal areas of Tanzania and Zanzibar amounted 54, 215, 664.1 m^3 and 12, 361,171.5 m^3 respectively. The stem volume is obviously closely related to stem biomass and also to tree biomass. And the same holds for carbon content. Therefore, the basic principles of volume functions do also hold for biomass functions and for carbon functions.

Table 5 Volume of coconut trees in coastal areas of mainland Tanzania

Total number of coconut trees	AGB + BGB (m^3)	Merchantable stem (m^3)	Total Volume (m^3)
25,000,000	12, 563, 791.5	41, 651, 872.6	54, 215, 664.1

AGB = above ground biomass, BGB = below ground biomass, m^3= cubic metres

Table 6 Volume of coconut trees in Zanzibar

Total number of coconut trees	AGB + BGB (m^3)	Merchantable stem (m^3)	Total Volume (m^3)
5,700,000	2, 864, 544.5	9, 496, 627	12, 361,171.5

AGB = above ground biomass, BGB = below ground biomass, m^3= cubic metres

Amount of Carbon stock of coconut trees in coastal areas of Tanzania

The results in Table 7 and Table 8 revealed that 52% of carbon stored in AGB (above ground) followed by merchantable stem (34%) and low carbon stored in BGB (below ground) of coconut trees in coastal areas of mainland Tanzania and Zanzibar. 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 coconut growing areas as emphasized much by Muyengi *et al*. (2015). Moreover, farmers with processed knowledge increase their income from coconut by products production.

Table 7 Carbon stock of coconut trees in coastal areas of mainland Tanzania

Total number of coconut trees	AGB (t)	BGB (t)	Merchantable stem (t)	Total C stock (t)
25,000,000	52, 850.94	14, 229.9	34, 609.04	101, 689.9

C= carbon, AGB = above ground biomass, BGB = below ground biomass, t= ton

Table 8 Carbon stock of coconut trees in Zanzibar

Total number of coconut trees	AGB (t)	BGB (t)	Merchantable stem (t)	Total C stock (t)
5,700,000	12, 050.01	3, 244.42	7, 890.86	23, 185.29

C= carbon, AGB = above ground biomass, BGB = below ground biomass, t= ton

Amount of profit to be accrued from carbon market of coconut trees in coastal areas of Tanzania

Tables 9 & 10 indicates average amount of money which should be accrued through carbon market by smallholder famers of coastal areas of mainland Tanzania and Zanzibar respectively if adopted REDD+ strategy. The average income of households will increase additional to coconut and coconut by-products which contributes average of TZS 326,668 per household as reported by Muyengi *et al*. (2015). However, the average accrued amount of money for individual coconut tree in carbon market is US$ 0.9 (TZS 2, 070). This result emphasizes improvement in production and productivity of coconut trees so that the accrued benefits can offset production cost resulting to improvement of livelihoods of coastal dwellers.

Table 9 Accrued profit of coconut trees in coastal areas of mainland Tanzania

Total number of coconut trees	AGB (US$)	BGB (US$)	Merchantable stem (US$)	Total C stock (US$)
25,000,000	211, 403.8	56, 919.6	138, 436.2	406, 759.5

C= carbon, AGB = above ground biomass, BGB = below ground biomass, US$ = United States dollar

Table 10 Accrued profit of coconut trees in Zanzibar

Total number of coconut trees	AGB (US$)	BGB (US$)	Merchantable stem (US$)	Total C stock (US$)
5,700,000	48, 200.06	12,977.67	31, 563.44	92, 741.17

C= carbon, AGB = above ground biomass, BGB = below ground biomass, US$ = United States dollar

4. CONCLUSION

This study estimated amount of biomass and carbon stocks of coconut (*Cocos nucifera*) trees in coastal areas of Tanzania. The findings have revealed that there are 10, 818, 072.1 tons and 2, 466, 520.5 tons of biomass equivalent to 101, 689.9 tons and 23, 185.29 tons of carbon stocks in coastal areas of mainland Tanzania and Zanzibar islands respectively. Furthermore, the carbon market can produce average total amount of US$ 406, 759.5 and US$ 92, 741.17 in coastal areas of mainland Tanzania and Zanzibar islands respectively. Therefore strengthening coconut 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.

Recommendations

The study provides the following recommendations for sustainable production, productivity, and utilization of coconut (*Cocos nucifera*) trees in coastal areas of Tanzania:

- The government and coconut famers should include these tree species into REDD+ scheme and use western paying principle scenario (i.e. all vegetation species should have equal values despite of their location);
- The government should provide fund for more scientific research on coconut production and productivity
- The government with coconut farmers should rehabilitate all old trees, apply fertilizers, weeding, and pest management to other existing coconut trees
- The government should provide extension services to coconut farmers so that the benefits can offset production cost.

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