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Estimating Amount of Biomassand Carbon Stock of Eastern Corridor of Selous-NiassaTFCA and its Contribution to Climate Change Adaptation

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Abstract

Countries' authorities that managing unfenced Protected Areas (PAs) as an effort to maintain biodiversity and ecosystem services,airs challenges of climate change and variability which disturb habitat and force wildlife to move to other unprotected areas for adaptation purposes. This scenario necessited the inclusion of those adapted areas into PAs network and recategorise the abandoned PAs. The unprotected areas include wildlife corridors which connects two or more PAs within the country or Transfrontier Conservation Areas (TFCAs). However, corridor dwellers unsustainably utilizing corridor fauna and flora for their livelihoods. This paper explains the less known amount of biomass and carbon stock of eastern Selous -Niassa wildlife corridor which connecting the two PAs of Tanzania and Mozambique. Specifically, the study estimates amount of biomass stock, amount of carbon stock and amount of conservation profit if adopted REDD+ strategy. Existing data on spatial and temporal land use and land cover of eastern corridor ofSelous -Niassa TFCA of 2016 was analysed to get intended results. The results reveled that, anaverage amount of 52738071tons and 13114780.2 tons of Biomass and Carbon stocks (above ground + below ground + deadwood) respectively for the year 2016. The amount of conservation profit of the area for the year 2016 wasestimated atUS$ 52459124 equivalents to US$ 119.79 per corridor dwellerif REDD+ strategies was adopted. Thisprofit seems to offset benefit received by corridor dwellers from their destructive activities. The foreseeable future necessitates inclusion of the area into core PAs, however, there is a cost which the government must incur in order to safeguard the adaptation scenarios of wildlife suffered from climate change and variability in core PAs without compromising livelihoods of corridor dwellers.

Keywords: Biomass; Carbon; Climate Change Mitigation and Adaptation; Land Uses

Introduction

Background Information

Terrestrial carbon sinks include soils, trees and other vegetation soaks up at least half of annual greenhouse gases emissions from fossil fuels resulting to slow down of climate-warming gases in our atmosphere[1]. Forests and woodlands play a great role in climate change. Forests can be a source of greenhouse gases, emitting carbon dioxide (CO_2) to the atmosphere when they are burnt, and also forests can act as carbon sink by removing CO_2 from the atmosphere and storing it as a carbon in their biomass as they grow.

Deforestation and forest degradation addressed as a low cost option to reduce greenhouse gas emissions and avoid an increase in temperature beyond acceptable levels seems to be sustainable strategy towards addressing climate change driving factors [1]. Tanzania is among of developing countries contributes high annual CO_2 emissions through deforestation and forest degradation amounted 126 million tons (deforestation 78 million tons, and forest degradation 48 million tons per year) [1]. CO_2 emissions contribute highly to global warming and climate change(World Bank, 2010; and Strange et al. 2011)[2,3]. Already global warming and climate changes have observed impacts on natural ecosystems and species [2,4,5]. Sub-Saharan Africa's ecosystems seem to be more vulnerable as climate changes cause extinctions of some species and affect their distribution, behavior, and reproduction of species, patterns and migrations.

Climate change is likely to accelerate the ongoing impoverishment of global biodiversity and degradation of ecosystems caused by unsustainable use of natural capital and other environmental stresses. Such degradation and disturbance in terrestrial and aquatic ecosystems generate niches that can be exploited by invasive alien species, leading tofurther ecosystem change and degradation. Global climate change can and has been caused by natural factors in the past, including shifts in the earth's orbit; circulation of the oceans; volcanic activity, or intensity of the sun. Currently, human anthropogenic activities are changing the climate through increasing the amount of greenhouse gases in the atmosphere.

Considering the impacts of climate change insisted the need for new conservation areas to fill connectivity gap between Protected Areas (PAs) through wildlife corridors so as to enable species migration with their climatic niche [6,7]. Connectivity of PAs through corridors advocacy adaptation of reserved fauna and flora under climate change. PAs are natural homes for the conservation of indigenous species that are resistant to pests, diseases and pathogens, environmental stresses and nutrient loss. PAs are also potentially beneficial as carbon sinks and for environmental conservation. The protection of corridor biodiversity relies on the ability to assess hot spots, quantify and predict spatial and temporal trends of key species maintain a natural disturbance regime and limit harmful human activities [8]. However, biological effectiveness of corridors is questionable by various scientists, arguing that established strategies focusing on PA aggregation and representativeness are more robust in the face of climate change [9]. Prioritizing new conservation areas and recategorize the abandoned PAs is a debatable new agenda; while, quantitative comparisons of the effectiveness of different PAs design strategies in retaining biodiversity over time are less documented[10,11]. Studies have applied dynamic landscape and metapopulation models to assess the relative benefits of corridors compared with larger terrestrial PAs and spatially dynamic versus static protected areas in maintaining populations for a focal species over time [12,13]. One of the primary limitations in quantitatively assessingthe effectiveness of alternative habitat configuration strategies has been the lack of suitable ecological modeling frameworks.

Problem Statement

Climate is changing and that changes are largely due toincreased levels of carbon emissions into the atmospherecaused by human activities. Global climate change is continuously caused by natural factors in the past, includingshifts in the earth's orbit or the circulation of theoceans, volcanic activity, or even the intensity of the sun. Currently human activities are changing the climate by increasingthe amount of greenhouse gases like carbon dioxidein the atmosphere. Increases in carbon emissionscome from burning fossil fuels, deforestation,developing land for farms, cities, and roads. The recommended response from society to climate changeinvolves two sets of activities: mitigation and adaptation.Mitigation is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases. Adaptationis the ability of a system to adjust to climate change (including variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences [1,14].

Adaptationaccepts that the climate is already changing and that increasedcarbon dioxide levels are the new reality that wemust plan for, including anticipated impacts from moresevere weather. Adaptation specificallyfor wildlife involves planning and taking actions that willallow wildlife to respond to this climate change with viablepopulations.As climate change exacerbates the threats thatare already on the landscape, thus the need for a new strategic framework for conservation is unavoidable [15]. This frameworkneeds to include new protected areas that account for species range shifts and management thataddresses large-scale change across international borders.

The aforementioned circumstancesnecessitate the need for Tanzania and Mozambique Governments to include eastern corridor of Selous -Niassa TFCA into the PAs ecosystem network that formulate the TFCA. However, the corridor dwellers unsustainably utilize available ecological resources for their livelihoods. The utilization involves conversion of corridor habitat to other land uses. Hence, this scenario calls for urgency estimating the amount of biomass and carbon stockof the corridor so as to plan for sustainable management strategies of the TFCA.

Objectives

Main objective

The main objective of this study was to estimate amount of biomass and carbon stock of eastern corridor of Selous-Niassa TFCA

Specific objectives

Specifically, the study intends to:

- Estimate amount of biomassstock of eastern corridor of Selous-Niassa TFCA.
- Estimate amount of carbon stock of eastern corridor of Selous-Niassa TFCA.
- Estimate amount of conservation profit of eastern corridor of Selous-Niassa TFCA.

Materials and Methods

Materials

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-NiassaWildlife Corridor (SNWC) which extends across southern Tanzania into northern Mozambique (Figure 1).Administratively passes in Liwale, Nachingwea,Masasi, and Nanyumbu Districts. Migration of elephants, buffalos and zebras has been observed [16,17]. Two migratory routes have been identified as follows:

(i) From Selous through Nahimba, Nakalonji, Mbondo, Kilimarondo, Matekwe and Kipindimbi proposed Game Reserve (GR) in Nachingwea District and then via Msanjesi, Mkumbalu, Sengenya, Nangomba and Nanyumbu in Nanyumbu District to Lukwika-LumesuleGR and then crosses Ruvuma River to the Niassa GR.

(ii) From Selous to Kiegei, Namatumu, Kilimarondo in Nachingwea then along Mbangala and Lumesule rivers to Mchenjeuka and Mitanga in the Lukwika-Lumesule GR, from where theycross the Ruvuma River to the Niassa Reserve.

These routes forms SNWC called Selous-Masasi corridor includes the Msanjesi (2,125 ha) and the Lukwika-Lumesule (44,420 ha) GRs in Masasi and Nanyumbu Districts respectively;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.

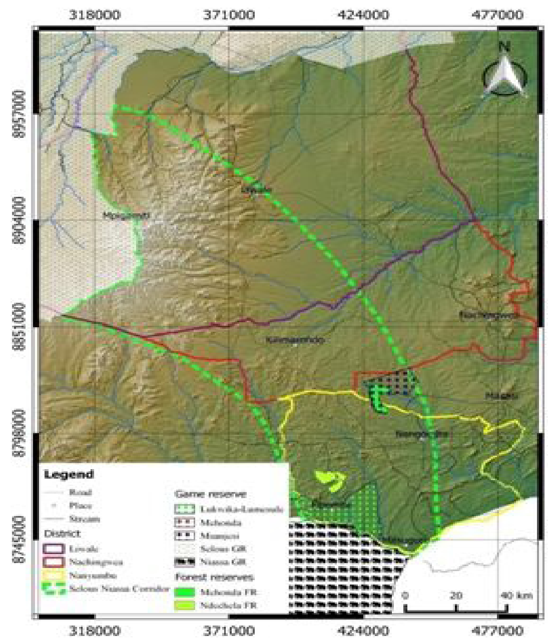

Figure 1: The Map of the study area.

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT	Total
Land use/cover area (ha)	89923	220217	480269	394461	646	268193	8851	1462560
Percentage (%)	6.15	15.06	32.84	26.97	0.04	18.34	0.61	100

CWD = Closed Woodland, **OWD** = Open Woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **BLT** = Built Up area, and **CL** = Cultivated land.

Table 1: Land use/cover area distribution of 2016.

Land cover class	Description
Closed woodland	Area of land covered low density trees forming open habitat with plenty of sunlight and limited shade
Open woodland	Area of land covered with low density and scattered trees with crop cultivation activities
Bushland	Area dominated with bushes and shrubs
Grassland	Land area dominated by grasses
Water	Area within body of land, of variable size, filled with water, localized in a basin, which rivers flow into or out of them (Lake/Dam)
Cultivated land	Farm with crops and harvested cropland
Built up area	Manmade infrastructure (roads and buildings) and settlement
Unclassified	Area with no input data or insufficient information which has been missed due to several reasons including clouds, clouds shadow, darkness, and sensor dysfunctioning

Table 2: Land use/cover classification scheme.

Data analysis

To estimate amount of biomass stock of eastern corridor of Selous-Niassa TFCA

Biomass Stocks

Living Biomass Stocks

Tanzania forest Carbon can be estimated in three pools namely AGB (Above Ground Biomass), BGB (Below Ground Biomass) and DW (Dead Wood) [18]. BGB was estimated as a fraction of AGB.AGB and BGB were estimated as follows:

- AGB (tonnes/ha) = Tree stem volume (m3/ha) × wood density/1000; and
- BGB (tonnes/ha) = AGB × 0.25 (as default), or root to shoot ratios.

URT (2015)[18]uses conversion factors into programmed NAFORMA analysis system by tree species or species groups to provide standards in each terrestrial ecosystem of Tanzania as shown in Table 3.

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT
Aboveground Biomass (t/ha)	59.5	27.7	11.0	2.9	4.6	5.9	2.9
Belowground Biomass (t/ha)	18.2	9.5	4.4	1.1	1.7	2.1	1.1
CWD = Closed Woodland, **OWD** = Open Woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **CL** = Cultivated land and **BLT** = Built Up area.							

Table 3: Living tree stemwood biomass by primary vegetation type.

Deadwood Biomass Stocks

Dead wood (DW) biomass is estimated from the volume computed using Smalian formula multiplied by wood density of 619 kg/m3[18].URT (2015) through NAFORMA reveals the dead wood Biomass of Tanzania (Table 4) is relatively low since most-dead wood in accessible areas is collected as fuelwood.As wood-lands are generally more accessible than forests, collection of deadwood for fuelwood from these areas is easier. The relatively high volume of dead wood in water is assumed to be because dead trees lying in areas with water / wetlands are difficult to access and decay slowly and because they are wet and therefore unattractive for fuelwood.

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT
Biomass (t/ha)	4.87	1.82	0.73	0.35	1.31	0.91	0.22
CWD = Closed Woodland, **OWD** = Open Woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **CL** = Cultivated land and **BLT** = Built Up area.							

Table 4: Dead wood biomass by primary vegetation type.

To estimate amount of carbon stock of eastern corridor of Selous-Niassa TFCA

Carbon Stocks

According to URT [18], carbon in terrestrial ecosystems of Tanzania can be computed as follows:

Carbon (tonnes/ha) = Biomass × 0.47

Living tree stemwoodand dead wood carbon (t/ha) by primary vegetation type are illustratedin(Table 5&6).

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT
Carbon (t/ha)	36.5	17.5	7.2	1.8	3.0	3.8	1.9
CWD = Closed Woodland, **OWD** = Open Woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **CL** = Cultivated land and **BLT** = Built Up area.							

Table 5: Living tree stemwoodCarbon (Aboveground + Belowground) by primary vegetation type.

Primary Vegetation Type	CWD	OWD	BS	GL	WTR	CL	BLT
Carbon (t/ha)	2.39	0.89	0.36	0.17	0.64	0.45	0.11
CWD = Closed Woodland, **OWD** = Open Woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **CL** = Cultivated land and **BLT** = Built Up area.							

Table 6: Dead wood Carbon by primary vegetation type.

To estimate amount of conservation profit of eastern corridor ofSelous-Niassa TFCA

The study adopted from Jenkins [19], and Loboraet al.[20] emphasized that, the standard carbon market is US$ 4 per ton if REDD+ strategy is implemented; this was used to estimate existing amount of money of conserving eastern corridor of Selous-Niassa TFCA.

Results and Discussion

Amount of biomass stock of eastern corridor of Selous-Niassa TFCA

The results in Table 7and Table 8revealed that, nearly 84.38% of biomass stock found in closed woodland (forests), open woodland and bushland. This implies that, amount of 12873004tons of biomass (above ground + below ground + deadwood)existing in closed woodland (forests), open woodland and bushland of eastern corridor of Selous -Niassa TFCA in 2016. Degradation of the area will impact negatively ecosystem services offered to wildlife residing or using the area for migration or adapting to climatic change.The degraded area converted to bushland, cultivated land and built up area due to increase of human population, livestock, and dependence of corridor dwellers on existing natural resources in the ecosystem for their livelihoods.These results necessitated formulation ofsustainable management strategy which will assure the survival of wildlife without compromising livelihoods of corridor dwellers. The existing formulation of Wildlife Management Areas (WMAs) of Liwale (MAGINGO), Nachingwea (NDONDA) and Nanyumbu (MCHIMALU) districts relies only adjacently to core PAs of Selous, Msanjesi and Lukwika-Lumesule game reserves, and forgetting other areas which are crucial to wildlife as their living habitat and migration trails.

Primary Vegetation Type	Total area (ha)	Above ground biomass stock (t/ha)	Below ground biomass stock (t/ha)	Total Biomass stock (t)	Biomass stock (%)
Closed woodland	89923	4.87	18.2	2074524	24.63
Open woodland	220217	1.82	9.5	2492856	29.59
Bushland	480269	0.73	4.4	2463780	29.25
Grassland	394461	0.35	1.1	571968.5	6.79
Water	646	1.31	1.7	1944.46	0.02
Cultivated land	268193	0.91	2.1	807260.9	9.58
Built up area	8851	0.22	1.1	11683.32	0.14

Table 7: Amount of living tree stemwood biomass (Aboveground + Belowground)stock of eastern corridor of Selous-Niassa TFCA.

Primary Vegetation Type	Total area (ha)	Biomassstock (t/ha)	Total Biomass stock (t)	Biomassstock (%)
Closed woodland	89923	4.87	1636599	23.89
Open woodland	220217	1.82	2092062	30.54
Bushland	480269	0.73	2113184	30.85
Grassland	394461	0.35	433907.1	6.34
Water	646	1.31	1098.2	0.02
Cultivated land	268193	0.91	563205.3	8.22
Built up area	8851	0.22	9736.1	0.14
Total			**6849790**	**100.00**

Table 8: Amount of dead wood biomass stock of eastern corridor of Selous-Niassa TFCA.

Amount of Carbon stock of eastern corridor of Selous-Niassa TFCA

The results in Table 9 and Table 10 revealed that, nearly 80.68% Carbon stored in closed woodland (forests), open woodland and bushland. This implies that, 11177730 tons of Carbon (above ground + below ground + deadwood) from closed woodland (forests), open woodland and bushland for the year2016. This is something that we can never stay quiet; and the need to act urgently is unquestionable. Conserving these vegetation is a climate change mitigation measure, but reacting now is adapting with mitigation measures for wildlife using the corridor as a migratory route or adapted area for their climatic niche. Thus, the need for sustainable utilization and management of natural resources in the area is vital. The need to include the area into core PA network is paramount, howeverthere is a cost (in terms of money or other areas suitable for their livelihoods) that the corridor dwellers have to accept as a compensation for releasing the area for protection. This cost can be regarded as an opportunity cost for corridor dwellers which the government must incur to officiate the process. For Tanzania scenario, we must agree that those areas abandoned by wildlife which previously used as PAs should be recategorise by considering all species ecology analysisin the face of climate change andhave proper management plan.

Amount of conservation profit of eastern corridor of Selous-Niassa TFCA

Results in Table 11 revealed that, eastern corridor of Selous -Niassa TFCA have Carbon stock equivalent to US$ 52459124forthe year 2016 if adopted REDD+ strategy. Estimated population of corridor dwellers of 2016 (using data of NBS, 2012) implies that, each individual wasexpected to gain nearlyUS$ 119.79 as a conservation profit in 2016.Consequently, closed woodland, open woodland, and bushland pioneered 85.22% of the conservation profit which could be gained from carbon trade. It seems that open and closed woodlands have potential hard wood species which are regarded as commercial rewarding but environmental destructive by corridor dwellers. Also, the Governmentearmarked those commercial rewarding tree species with their prices; but administer-

Primary Vegetation Type	Total area (ha)	Carbon stock (t/ha)	Total Biomass stock (t)	Share (%)
Closed woodland	89923	36.5	3282190	26.59
Open woodland	220217	17.5	3853798	31.22
Bushland	480269	7.2	3457937	28.02
Grassland	394461	1.8	710029.8	5.75
Water	646	3.0	1938	0.02
Cultivated land	268193	3.8	1019133	8.26
Built up area	8851	1.9	16816.9	0.14
Total			**12341842**	**100**

Table 9: Amount of living tree stemwood Carbon (Aboveground + Belowground) stock of eastern corridor of Selous-Niassa TFCA.

Primary Vegetation Type	Total area(ha)	Carbon stock (t/ha)	Total Biomass stock (t)	Share (%)
Closed woodland	89923	2.39	214916	27.81
Open woodland	220217	0.89	195993.1	25.36
Bushland	480269	0.36	172896.8	22.36
Grassland	394461	0.17	67058.37	8.68
Water	646	0.64	413.44	0.05
Cultivated land	268193	0.45	120686.9	15.61
Built up area	8851	0.11	973.61	0.13
Total			**6849790**	**100.00**

Table 10: Amount of dead wood Carbon stock of eastern corridor of Selous-Niassa TFCA.

ing their utilization and their market chain are questionable.Thus, we need community centered decision making which is integrated but different from PFM (Participatory Forest Management), JFM (Joint Forest Management) and WMA (Wildlife Management Areas) because they really not fully integrate targeted population and they cannot benefit individual entity in the community. Also, all these scenarios do not consider that those individuals in the community are changing in time, thus, scientific revised community members monitoring strategy and recording system is unavoidable; and emphasis of integrative participatory approach as advocated by Pimbert and Prety (1995)[21].

Primary Vegetation Type	Total area(ha)	Carbon stock (t/ha)	Total Biomass stock (t)
Closed woodland	3497106	13988424	26.66
Open woodland	4049791	16199164	30.87
Bushland	3630834	14523335	27.69
Grassland	777088.2	3108353	5.93
Water	2351.44	9405.76	0.02
Cultivated land	1139820	4559280	8.69
Built up area	17790.51	71162.04	0.14
Total	**13114781**	**52459124**	**100**

Table 11: Amount of conservation profit of eastern corridor of Selous-Niassa TFCA.

Conclusion

This study estimated amount of biomass and carbon stocks of eastern corridor of Selous -NiassaTFCAfor the year 2016. The findings have revealed that, the study area has a notable Biomass and Carbon stocks of anestimated amount of 52738071tons and 13114780.2 tons of Biomass and Carbon stocks (above ground + below ground + deadwood) respectively. The carbon market seems to provide an amount of US$ 52459124 for the year 2016if and only if REDD+ strategy could be adopted. Thisamount of conservation profit of the area seems to offset amount of benefit received by corridor dwellers from their destructive activities. The foreseeable future necessitates inclusion of the area into core PAs; or formulation of management strategies that will safeguard the adaptation scenarios of wildlife suffered from climate change and variability in core PAs without compromising livelihoods of corridor dwellers.

Recommendations

The study provides the following recommendations for sustainable management and conservation of eastern Selous -Niassa TFCA:

- The government and corridor dwellers should include the area in REDD+ scheme and use western paying principle scenario (i.e. all vegetation species should have equal values despite of their location);
- For short and mediumterm strategies; the government and corridor dwellers should enhance the existing Wildlife Management Areas (WMAs), Participatory Forests Managements (PFMs) and Joint Forests Managements (JFMs) so that, nearly 90% of the corridor to be under PAs management of different categories;
- The government should formulate user friendly guidelines for protection of wildlife corridors as stipulated in Tanzania Wildlife Conservation Act No. 5 of 2009;
- The government in collaboration with other stakeholders should initiate cost effective and environmental friendly source of energy different from fuelwood.

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