

Forest Biomass Management Challenges in Commercially Exotic Tree Plantation Areas: A Case Study from the Rungwe Volcanic Province (Southern Highlands of Tanzania)

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Abstract

The carbon (C) stored in the living biomass of trees is typically the largest C pool of the forest ecosystem which is directly impacted by deforestation and degradation. With the global efforts to combat climate change through a forestation and reforestation to reduce carbon emissions in the atmosphere, natural forests conservation and tree planting programmes are highly emphasized in developing countries for both commercial purposes and carbon emissions reduction. Though most of the trees planted are exotic trees especially *Pinus patula*, *Eucalyptus saligina* and partly *Cypress* sp. with some fruit and shade trees in towns. When comparing survival and carbon content of exotic and indigenous trees grown, exotic trees have high initial biomass and growth rate while indigenous trees perform better in survival rates; also indigenous forest sequesters more above ground biomass (C) and soil carbon than exotic plantations. Hence embarking on clearance of forest's indigenous trees for plantation of commercial exotic trees slightly slows down the efforts of carbon emission reduction and mitigation of climate change through enhancement of carbon sequesters. Therefore, this calls for the need to assess how individual tree planting programs lead into natural forest's encroachment. The study was conducted at Mbeya One ward lying between Mporoto and Rungwe forest reserves in Mbeya rural district, in the Southern highlands of Tanzania. The main objective was 1) to assess the indigenous tree biomass variation between Mporoto and Rungwe forest reserves; 2) to assess the exotic tree biomass variation between the two forest reserves; and 3) to assess the human implication on aboveground biomass variation between the two forest reserves. The findings indicated significant decrease in indigenous trees biomass in residential and crop land areas with a hasty increase in biomass when just reaching Mporoto forest reserve indicating little human encroachment in the forest re-

serve. There was the same trend towards Rungwe forest reserve; however, there was a slight increase in indigenous tree biomass when reaching forest reserve signing presence of human encroachment in the forest reserve. The main human activities observed in the reserve were: timber harvesting and commercial exotic trees planting (especially the commercial trees, *Pinus patula*). The trend was opposite for the exotic trees especially for *Pinus patula* and *Eucalyptus* sp. in the study area. Hence the study concludes that there is a significant variation between indigenous and exotic trees in the study area, hence the variation in the tree biomass. There is also a massive human encroachment for indigenous trees clearance in expense of exotic trees plantations towards and in Rungwe forest reserve. Therefore, the study would like to call for an urgent intervention especially in the east side of the study area (Rungwe forest reserve) stopping exotic tree plantation penetrating into the forest reserve which intensifies cutting down of indigenous trees in the forest reserves plummeting above ground biomass and escalating carbon emissions in the atmosphere while jeopardizing the natural forest ecosystem services to the communities. Conservation education should be emphasized in the study area to local communities, exotic trees plantations owners and other relevant stakeholders.

Keywords

Forest Reserve, Indigenous Trees, Exotic Trees, Biomass Variation, Human Encroachment

1. Introduction

Most of the tropical natural forests have been for centuries playing key roles in traditional, socio-economic and ecological wellbeing of most of the communities living around forests and the country at large, through provision of livelihoods and ecological services [1]. However the actions of accruing these services augmented with increase in population have resulted in forest deforestation and degradation. Forest deforestation and degradation have mainly been caused by tree harvesting for timber, logging, agricultural expansion and firewood collection with its negative impacts on species diversity and forest tree composition and carbon quantities.

The carbon (C) stored in the living biomass of trees is typically the largest C pool of the forest ecosystem which is directly impacted by deforestation and degradation [2]. The relationships between diversity, biomass and C stocks at varied altitudes can have crucial implications for the management and conservation of C sinks [abid]. Natural tropical forests have been for centuries playing a key role in carbon sequestration from the atmosphere hence functioning as carbon sinks and helping to balance the concentration of CO₂ in the atmosphere. But with the expansion in trade, industries and agriculture, most of the forest reserves have been facing deforestation through illegal logging, timber harvesting, plantations of exotic trees and expansion of agriculture in natural intact fo-

rests. Making deforestation the second largest human induced source of carbon dioxide in the atmosphere [3] [4].

Global instruments to reward countries embarking on reduced deforestation and degradation (REDD) and application of sustainable management of forest services (REDD+) to enhance carbon sequestration recognize the significance of indigenous tropical forest trees in carbon emissions sequestration capacity and mitigation of climate change [5] [6]. However the amount of biomass and carbon on site is largely determined by human activities and management mechanisms. [5] [6] showed that tree biomass and soil carbon densities in indigenous forests were not consistently greater than in plantations of exotics, depending on the plantations age and species. Although Meta analysis studies have shown that replacing native forests with agriculture and plantations (when less than 40 years of age) generally reduces soil carbon stock [7] [8] [9]. This indicates how plantations of commercial exotic trees have little capacity in storing carbon in its ecosystem and hence are less liable for carbon sequestration and climate change mitigation because in the study area, it was observed that *Pinus patula* was ready for timber harvest (when 10 and above years age). While studies show that, a typical Tree Plantation investment could generate few profits in 20 years for wood pellets, veneer in year 25 and timber after year 30 [10] [11].

The study was conducted at Mbeya One ward between two forest reserves (Rungwe forest reserve in the east and Mporoto forest reserve in the west) in Mbeya rural district, Mbeya region. The main objective was to assess the influence of human activities on biomass variation of indigenous village and forest reserve trees between two forest reserves and the specific objectives were: 1) to assess the indigenous tree biomass variation between Mporoto and Rungwe forest reserves; 2) to assess the exotic tree biomass variation between the two forest reserves; and 3) to assess the human implication on the variation of tree's biomass between the two forest reserves.

2. Methodology

2.1. Description the Study Area

Rungwe Mountain Forest Reserve is located in Rungwe District of Mbeya Region in the south-western part of Tanzania. It is found between latitudes 9°02' and 9°12'S and longitudes 33°35' and 33°45'E. To the east, the forest is bordered with the Kitulo National Park and the Mporoto Ridge Forest Reserve that has an impressive crater of Lake Ngozi bordering the forest to the northwestern parts [12]. Geographically the crater is part of the Mporoto Ridge forest reserve with Ngozi peak at 2620 m the highest point of the ridge.

Rungwe Mountain is the southern Tanzania's second highest peak rising up to 2960 m above sea level; it is composed of 10 or more dormant volcanic craters and domes, the mountain is surrounded by the catchments forest reserve that gazetted in 1949, which incorporates montane forest, upper montane forest and montane grassland, with lesser amounts of bushland and heath at the upper elevations found in low bushes along streams and at the edges of montane forest.

2.3. Data Analysis

To determine the above ground biomass and volume of each tree, the allometric equations developed by Malimbwi *et al.* (2003) cited by [14] was used. According to Malimbwi (2003), both above ground biomass and volume are the function of tree height and diameter regardless of the species type.

The Tree Biomass Equations used are given below.

$$\text{Height} = \text{Exp}(0.58048 + 0.602965 \text{Ln}D) \quad (1)$$

$$\text{Above ground biomass} = 0.06D^{2.012}H^{0.71} \quad (2)$$

where; D is the diameter at breast height in centimeters (cm), H is the height in meters (m) of each tree.

Tree abundance in both sides of the study area (*i.e.* Mporoto forest reserve side and Rungwe forest reserve side) was compared by using Shannon Weiver Species richness index (H) [15]

$$H = -\sum (pi \text{Ln}Pi)$$

where: Pi is the proportion of species i relative to the total number of species Ln pi the natural logarithm of this proportion pi .

3. Results

A total of eighteen (18) plots were established of which two (2) plots were established in each forest reserve, having a total of four (4) plots in the forests and 14 plots in the crop and residential areas. Plots were established at various altitudes ranged between 1448 m to 2034 m a.s.l.

3.1. Variation of Indigenous Tree Biomass along the Transect

Findings shows that, the biomass of indigenous trees decreased along the transect as one moves from one forest reserve to the crop land and residential areas then began increasing when approaching the next forest reserve, this indicates that establishment of field crops involved clearance of indigenous trees, this was also observed in exotic tree plantations where there were still some indigenous trees left in the plantations.

From **Figure 2**, gentle and undulating sloping of the graph (at 0 - 1000 m) indicated the presence of little or no forest encroachment through tree cutting in Mporoto forest reserve when compared with Rungwe forest reserve where the forest is intact at around 7000 m along the transect but with a sharp decline at 6000 m. This trend shown that, there were human encroachments for tree cutting on the side of Rungwe forest reserve.

3.2. Variation of Exotic Tree Biomass along the Transect

The main commercial exotic trees in the study area were *Eucalyptus saligna* and *Pinus patula* followed with scarcely distributed residential fruit trees like *Persia americana*, *Prunus americana* and *Mussa sapientum*. There was an interchanging trend of biomass variation between indigenous and exotic trees in the study

area. As one moves from Mporoto forest reserve in the west, exotic tree biomass was very small though began to increase when entering crop lands and near residential areas. However as in **Figure 3**, exotic trees biomass increased rapidly near the Rungwe forest reserve boundary and after the boundary (**Figure 3**, around 5000 - 7000 m along the transect) with a gentle decrease at 500 m along the transect where there were indigenous trees, this indicated that human encroachment into the forest has replaced the indigenous trees especially through clearing indigenous trees replacing with exotic trees.

3.3. Variation of Indigenous Tree Richness along the Transect

There was high variation in tree species richness towards Mporoto and Rungwe forest reserve (Shannon index, $H = 1.9677$ and 1.37593 respectively), with dominating indigenous tree species in crop lands and plantations in both sides were *Hagenia abyssinica*, *Olea europaea* and *Halleria lucida*. The indigenous tree abundance varied in an undulating pattern (**Figure 4**) with main tree species *Hagenia abyssinica* found in all land use types while *Halleria lucida* were mainly found in crop lands. Presence of the some common indigenous trees in cropland and residential areas on both sides of highway which separates the study area, indicates that may be before invasion of people into the land and construction of

Variation of Indigenous tree's Biomass along the Transect

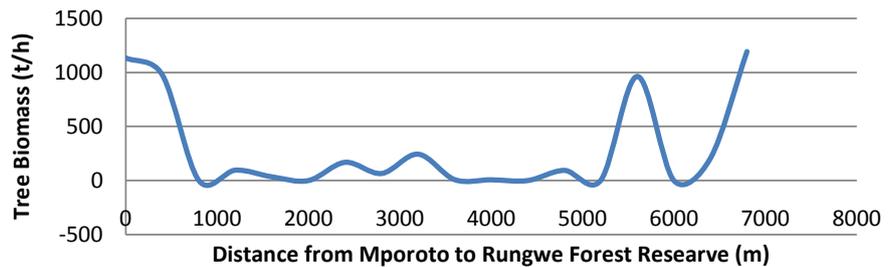


Figure 2. Indigenous tree biomass along the transect.

Variation of Exotic tree's Biomass along the Transect

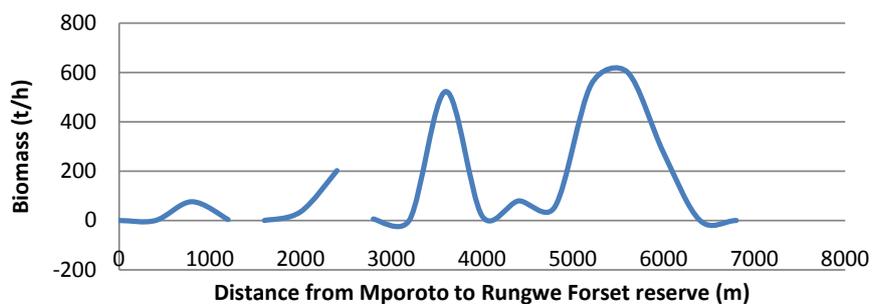


Figure 3. Indigenous tree biomass along the transect.

the highway road the two forest reserves were connected and human being encroached the forests through tree clearance for crop cultivation and residents, a trend which is still going on though in a slow pace toward Rungwe forest reserve.

3.4. Variation of Exotic Tree Abundance along the Transect

The trend of exotic trees abundance along the transect corresponds positively with the trend of indigenous trees but in opposite pattern (Figure 4). From Mporoto forest reserve, exotic trees began planted just after the forest reserve boundary followed by Irish potatoes and maize fields and the trend was increasing towards residential areas. The trend was contrary on the other side of the highway towards Rungwe forest reserve where plantation of exotic trees began in the forest reserve and went down all the way to crop land and to the residential area. This indicates that on the side of Mporoto forest reserve, exotic trees has been planted in the people’s own fields while in the side of Rungwe forest reserve there is some sort of forest reserve encroachment for exotic trees plantation (Figure 5).

The number of exotic tree species on the side of Mporoto forest reserve was higher compared to Rungwe forest reserve side, this may be due to the observed fact that the dominating exotic tree species on the Rungwe forest side is *Pinus*

Variation of Indeginous Trees along Transect

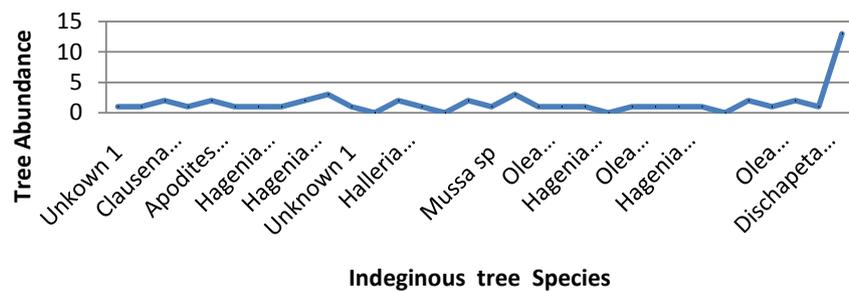


Figure 4. Variation of indigenous tree abundance along the Transect.

Exotic trees variation along Transect

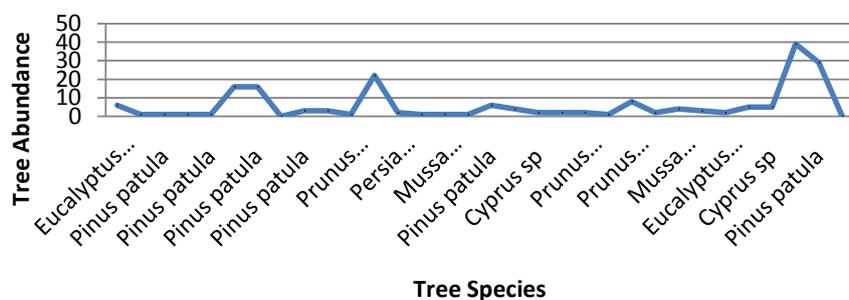


Figure 5. Variation of indigenous tree abundance along the Transect.

patula which is basically for timber business while on Mporoto side two exotic tree species dominated including *Eucaryptus saligina* and *Pinus patula* which were for timber and poles business. Therefore Mporoto side was more diverse ($H = 1.1831$) when compared to Rungwe forest side ($H = 0.7415$).

4. Conclusion and Recommendation

4.1. Conclusion

There is a clear interchanging trend of both indigenous and exotic tree's biomass variation along the transect in the study area, indicating that exotic tree plantation has replaced indigenous trees in the area while in the crop lands most of indigenous trees have been cleared for crop cultivation, which is still going on though slowly; if not intervened it will result in conversion of much of the forest land into exotic trees plantations and crop cultivation especially a commercial crop *Irish potatoes*. This will lead to loss of a potential carbon sink as most of the indigenous trees store more carbon when compared with exotic trees which grow at fast rate and start being harvested in short life time (8 - 10 years) for timber production. While in a long run, this trend leads to depletion of the potential of natural forests in ecological and social services like losing water conserving trees in water sources hence lowering water reserve and availability not only in the surrounding communities in villages but also in towns and cities where the main water supply is from rivers draining down from mountain forests. The trend will also have a negative impact on the wild animals, some endemic and threatened dwelling in the forest reserves and the aesthetic nature of the area to tourists.

4.2. Recommendation

There should be an urgent intervention especially in the east side of the study area (towards Rungwe forest reserve) stopping exotic tree plantation penetrating into the forest reserve, timber harvesting and Irish potatoes cultivation, plummeting aboveground biomass and escalating carbon emissions in the atmosphere while jeopardizing the natural forest ecosystem services to the communities. Conservation education should be emphasized in the study area to local communities, exotic trees plantations owners and other relevant stakeholders.

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