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*Original Article*

# Tree Species Density and Basal Area in Image Forest Reserve, Tanzania

*Dr. Canisius John Kayombo, PhD[1*], Dr. Henry Joseph Ndangalasi, PhD[2], Richard Alphonce Giliba[3], & Imani Kikoti[4]*

[1] Forestry Training Institute, Olmotonyi, P. O. Box 943, Arusha.
[2] Department of Botany, College of Natural and Applied Sciences, The University of Dar es Salaam, P. O. Box 35060, Dar es Salaam, Tanzania.
[3] School of Life Sciences and Bio-Engineering, The Nelson Mandela African Institution of Science and Technology, P. O. Box 447, Arusha, Tanzania.
[4] Tanzania National Parks (TANAPA), P. O. Box 313, Arusha, Tanzania.
[*] Author for Correspondence ORCID: https://orcid.org/0000-0002-8149-895X ; email: kayombocanisius@gmail.com.

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## ABSTRACT

The tree species density and basal area form structural and functional variables of healthy forest ecosystems. Tree density and basal area are among useful parameters for management of natural forest resources. A study was carried out in Image Forest Reserve (IFR) in 2019 to determine tree species density and basal area. A total of 170 plots measuring 20 m x 40 m were set along the land cover types at an interval of 250 m from each other. Trees with a diameter at breast height (DBH - cm) ≥ 5 cm were measured for their DBH at a height of 1.3 m from ground level and used to calculate the basal area (BA) ($m^2$). The tree individuals were used to calculate the density (D). The largest basal area was recorded from forest cover (13 279 $m^2$ $ha^{-1}$), followed by woodland (4394.09 $m^2$ $ha^{-1}$), and wooded grassland was the least). The minimum BA was recorded from woodland, while the largest was from forest (6.881 $m^2$ $ha^{-1}$). In all land cover types the DBH class (cm) >40 cm had the largest BA. Woodland had the highest density of all other land cover types, followed by forest and wooded grassland was the least. The maximum density was recorded from woodland followed by forest and wooded grassland.

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## INTRODUCTION

Forests are rich repositories of biodiversity, as they provide various ecosystem services important to sustain rural livelihoods and national development (Tenzin *et al.*, 2017). The ecosystem services are particularly food, water catchment service, reduction of soil erosion through running water during heavy rains and wind blow, windbreak, fuel wood, construction materials, and livestock fodder to mention a few. The trees density and basal areas are potential parameters for determining the population structure in forest reserves (Loef *et al*., 2019). The density provides information for plants coverage per unit area better understanding of survival risks and uncertainties (Gadow & Kotze, 2014). It has been stated that tree density and productivity are important structural and functional variables of the forest ecosystems (Fatehi *et al*., 2017). Tree density provides, indirectly, information on stands basal area, timber volume and above-ground carbon storage (Eilu *et al.*, 2004). In managed forest ecosystems, tree density information allows forest managers to identify essential treatments such as thinning, or to develop strategies to increase regeneration rates (Loef *et al*., 2019).

If the number of trees is too small, particularly in protected forests, their density is crucial to determine the succession dynamics and to assess spatial temporal patterns in tree mortality (Fatehi *et al*., 2017). To increase the number of stems of any declining tree species restoration through planting on forest or woodland gaps can be practiced. Plant species density describes the number of individual plants in a given area (Mahajan & Fatima, 2017). Density is an attribute that is most often applied to larger plants, such as trees, shrubs, and more prominent perennial forbs (Erenso *et al*., 2014). Plant density changes are simply caused by either increase or decrease in the number of individuals per unit ground area (Park *et al*., 2003). The increase in number of stems will increase the density value, while the decrease in number of individuals leads to decrease in the value of density (Xiao *et al*., 2006). The plant species density is determined to reveal the distribution and abundance of a particular species in a specified locality (Wiebel & Alfold, 2007).

Density is often used as a baseline inventory of the structure of rangeland or forest vegetation, by quantifying different individuals of species ages (Schulz *et al*., 2009; Zilliox & Gosselin, 2014). It is determined by counting the number of individuals of a species in uniformly sized sample plots within a site (Carvalho & Batalha, 2013; Gadow & Klotze, 2014). Density data are used to monitor the effect of various land use treatments, such as plant survival following burning or herbicide application, particularly for woody species (Miller & Miller, 2004; Liu *et al*., 2017). Minden *et al* (2016) reported that local management is an important driver of species density across a particular landscape. The density is directly and positively driven by management, with consistently negative effects of total biomass (Farmilo *et al*., 2014).

The factors for the decline of tree species density at Image Forest Reserve include illegal activities

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particularly; wildfires, logging for timber, and grazing. Logging causes a significant decline of density of trees as individuals for determining the density are being removed, whereas the standing trees basal area is being reduced as the measurable stems are being removed (Behjou & Mollabashi, 2017). Wildfires clear or burn the plants and thus reduce the number of stems that are among parameters for density determination. Livestock grazing damages seedbank, seedlings, and saplings through trampling effect and breaking of leaves and branches for those trees that are fed on by livestock (Arroyo-Vargs *et al.*, 2019). Torres & Lovett (2013) described that tree basal area is the sum of the cross-sectional surface areas of each live tree, measured for its diameter at breast height. Mugasha *et al.* (2013) reported a per unit area basis; basal area is among measure of tree density, and widely used in forestry, wildlife, and other natural resource management professions (Tenzin *et al*., 2017). The basal area is highly dependent on the tree diameter which is used as a measure of competition among trees per unit area (Mugasha *et al.*, 2013). pointed out that density and basal area differ among vegetation types whereby one of them may be greater than the other because of the relatively favourable growing conditions. It has been explained that the vegetation types in warm and humid regions tend to vary toward greater stem density and basal area than those in more arid regions and cooler latitudes (Fang *et al*., 2002).

Image Forest Reserve is characterized by a variety of vegetation types that harbour high plant species density, but is inadequately studied. The natural forest, woodland, and wooded grassland are occupied by high plant species density, however little information exists on density and basal area. Lovett and Congdon (1990); Minja (1991) highlighted on the plant species diversity of Image Forest Reserve, specifically, of the Selebu hill top, while little is known on the tree's density and basal area of the specific locality This study intended to determine the tree species density and basal area in Image Forest Reserve. It was necessary to determine the density to find out the number individuals of species per hectare. Basal area was meant to reveal the sizes of trees on land cover types. The identified drivers that lead to the decline in tree species density and basal area create awareness potential to conservation agencies while implementing conservation and protection plans to maintain the health of natural resources of Image Forest Reserve. In this study, it was hypothesized that there was a significant difference in the tree species density and basal area among the forest, woodland, wooded grassland, shrubland and grassland in of Image Forest Reserve.

## MATERIAL AND METHODS

### Location of Study Area

Image Forest Reserve (IFR) is situated in Kilolo District, Iringa Region in the Southern Highlands of Tanzania. IFR experiences oceanic rainfall (cooling warm air currents from Indian Ocean), with continental temperatures, with only one rainy season that span from November to April, experiencing an annual rainfall of 1500 mm; annual temperature of 20 $^0$C ± 15 $^0$C (Minja, 1991; Ruffo, 1991; Lovett and Clarke 1998; United Republic of Tanzania, 2013). It lies in an area with rolling hills and attractive plateaus at an altitude of 1640 to 2440 m (Ruffo, 1991). The site consists of a diverse vegetation type including forest, woodland, wooded grassland (*Figure 1)*. The landscape is divided into riverine, valleys and ridge tops within forest reserve. The woodland is mainly found at the bottom of Afromontane Forest and on top ridges of spurs. Wooded grassland lies within Afromontane Forest gaps with scattered trees or emerging tree clumps, shrubs, grasses, herbs, and ferns.

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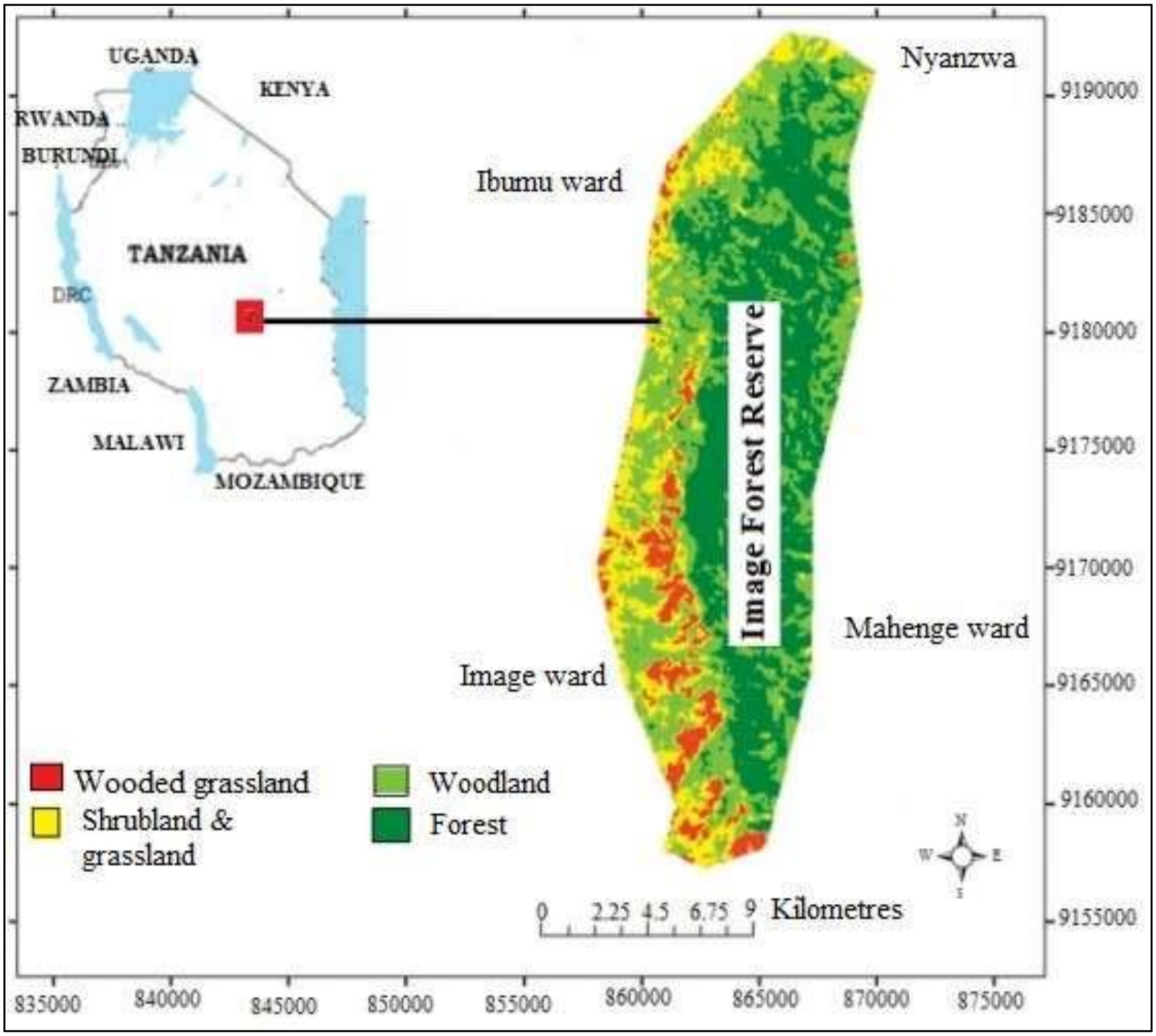
**Figure 1: Study area of Image Forest Reserve**




## Data Collection

The coefficient of variation (CV) formula (Conquest 1983), and adopted from Ospina and Marmole Ramos (2019), was used to calculate the sample size, through; $n = \frac{CV^2 t^2}{E^2}$, n = number of plots (sample size); CV = coefficient of variation; t = value of student "t" from the student distribution table at $n^{th}$ degree of freedom of the pilot study trial study plots at 5% probability; E = sampling error. CV is a useful statistic for comparing the degree of variation from one data series to another even if the means are drastically different from one another (Conquest, 1983). A total of 170, 20 m × 40 m, through Modified Whittaker (1995), and adopted by FAO (2007), where nested plots were established. Each plot was set each at an interval of 250 along the identified land cover types; 67 in the forest, 64 in the woodland, 39 in the wooded grassland. The trees with a diameter ≥ 5 cm (Heo *et al*., 2019), were identified and measured at 1.3 m from ground using a diameter tape and identified to species level. When immediate identification was not possible, plant specimens were collected for comparison and use of keys on FTEA at the University of Dar Es Salaam Herbarium (DSM) of the Botany Department at the University of Dar es Salaam.

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**Data Analysis**

The measured diameter in centimetres was used to calculate the basal area (BA) as per Elledge and Barlow (2020). The numbers of stems (number of individuals of trees) were used to determine the trees density (D).

**Equations**

$$BA(m^2) = \frac{3.14*(DBH(cm)^2}{4*100\ cm} \qquad [1]$$

Where BA = basal area; DBH = diameter at breast height (1.3 m); and 3.14 & 4 are constants.

Density (D)

$$D = \frac{n(no.of\ individuals)}{PA(Ha)} \qquad [2]$$

Where; D = density; n = number of individuals (no. of stems of an identified tree); PA = plot area in hectares.

**RESULTS**

**Tree Species Density**

The tree species recorded density varied within the land cover types in Image Forest Reserve (IFR). Woodland had the highest density of all other land cover types (417.188), followed by forest (354.10), while wooded grassland was ranked the least (59.285) (*Table 1*). Wooded grassland had the highest minimum tree density of all other land cover types (0.321), followed by woodland (0.195), and forest (0.187) (*Table 1*). The tree species with minimum density in the forest were;

*Dombeya rotundifolia*, *Euphorbia sp.*, *Faure saligna*, *Flueggea virosa*, *Hymenodictyon floribundum*, *Kigelia africana*, *Markhamia acuminata*, *Olea capensis*, *Cussonia zimmermannii*, *Diospyros loureiroana*, *Schefflera volkensii*, *Schefflera goetzei*, *Strychnos lucens*, *Syzygium guineense*, *and Trema orientalis*. The maximum density was recorded in *Maesa lanceolata*. The woodland minimum density (0.195) tree species were *Acacia nilotica*, *Brachysegia boehmii*, *Commiphora eminii*, *Dalbergia boehmii*, *Faurea speciosa*, *Hymenodictyon parvifolium*, *Maesa lanceolata*, *Mystroxylon aethiopicum*, *Ozoroa insigns*, *Pavetta schummaniana*, *Protea madiensis*, *Psorospermum febrifugum*, *Rauvolfia caffra*, *Rothmania engleriana*, *Rourea orientalis*, *Empogona lanceolata*, *Vangueria madagascariensis*, *Gymnanthemum amygdalina* , *Vitex doniana* (*Appendix 1*). The minimum density (0.321) for wooded grassland was recorded from *Ficus ingens*, *Ormocarpum kirkii*, *Phoenix reclinata Rhus vulgaris*, *Senna singuena*. The maximum density (6.090) was recorded from *Brachystegia spiciformis*.

**Table 1: Density, Minimum and Maximum Density per Land Cover**

| Land cover | S | Density | Min Density | Max Density | Min RD | MaxRD |
|---|---|---|---|---|---|---|
| Forest | 109 | 354.10 | 0.187 | 32.09 | 0.053 | 9.062 |
| Woodland | 93 | 417.188 | 0.195 | 140.820 | 0.047 | 33.755 |
| Wooded grassland | 56 | 59.285 | 0.321 | 10.27 | 0.541 | 9.189 |

*Key: S = species richness; RD=Relative Density*

**Tree Species Basal Area Per Land Cover Type**

The forest cover recorded the highest basal area (BA) (13 279.86 $m^2$ $ha^{-1}$), followed by woodland (4,394.09 $m^2$ $ha^{-1}$), and wooded grassland was ranked the least (433.012 $m^2$ $ha^{-1}$) *(Table 2)*. The diameter class >40 had the largest captured the highest basal area of all other classes *(Table 2)*. The tree species with the minimum BA was *Kigelia africana* (0.196 $m^2$ $ha^{-1}$), while the trees with maximum BA (1,396.65 $m^2$ $ha^{-1}$) was *Dombeya rotundifolia.*

 

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### Mean Basal Area (MBA) per land cover Type

The forest cover had the largest mean basal area (6.881 $m^2$ $ha^{-1}$) of all others, followed by wooded grassland (2.341 $m^2$ $ha^{-1}$), and woodland was the least (2.05 $m^2$ $ha^{-1}$) *(Table 3)*.

**Table 3: Mean basal area per land cover**

| Land cover | Individuals | DBH (cm) | BA ($m^2$) | MDBH (cm) | MBA ($m^2$) |
|---|---|---|---|---|---|
| Forest | 1930 | 42 915.50 | 13 279.86 | 22.236 | 6.881 |
| Woodland | 2143 | 27 518.60 | 4394.09 | 12.841 | 2.05 |
| Wooded grassland | 185 | 2387.60 | 433.012 | 12.905 | 2.341 |
| **Total** | **4 258** | **72 821.70** | **18 106.96** | **47.982** | **11.272** |

## DISCUSSION

The density indicates how dominant a certain species is in a given locality, and thus contributing to the judgement of its abundance comparing to other species (Netto *et al.,* 2015). The density of trees can predict health status of forest (Baker *et al*., 2004). The largest basal area was contributed by the measured large DBH (cm) sized. The forest cover results were revealed to have the highest basal area, followed by woodland, and wooded grassland. The highest density was revealed on woodland, followed by forest cover, and wooded grassland was the least. The forest cover had higher density and basal area than other land cover types *(Table 1*). The higher density and basal area, especially in the forest was probably contributed by minimal human disturbances on tree stems and larger size of the measured trees. It has been reported that density is positively correlated with patch size, but negatively correlated with isolation (Henry *et al*., 1999; Carpenter, 2005; Pastur, 2007; & Mugasha *et al*., 2014).

Farmilo *et al* (2014), observed that species density in small fragments was higher than continuous forest for all species groupings at small spatial scale. (Livingston and Sittlehouse, 1993) observed that the density and basal area of riparian forests was greater than that of upland forests because of the relatively favourable growing conditions including water supporting their growth performance. Probably, this might be because the forest trees growth was supported by reliable rainfall, and minimal human disturbance as among drivers of change in tree density favoured by both number of stems and large tree diameter. The woodland trees were rather impacted with various human activities including wildfires, illegal logging, and grazing. These supported trees with less diameter than in forest, while wooded grassland was contributed by scattered stems, as the vegetation was a rather grassland that is undergoing a transition to woodland, and wooded grassland supported fewer trees that the forest and woodland. Makunga & Misana (2017), stated that soil, topography, and biophysical factors such as wildfires are among factors that determine plant species integration.

Blomley and Iddi (2009), pointed out that most useful trees are monitored well by conservators after having determined for their size classes through focusing on the likely to be demanded size and hence arranging conservation. The largest basal area and highest density for the DBH-class >40 cm in the forest cover was contributed by the size of the measured and counted trees than the other vegetation structures. The merchantable timber trees are from larger diameter class that are likely to encourage illegal harvesting, and hence changing tree density, which depends on the number of standing tree stems per unit area (Blomley & Iddi 2009). Rouvinen and Kuuluvainen (2004), results demonstrate that high variability of tree sizes and stand structures is an important feature of natural plant population dynamics in the forest. Rocky and

 

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Mligo (2012), in a study at Pugu Forest Reserve pointed out that many trees with size classes below 35 cm diameter is an indication that some individuals beyond these size classes are missing. This implies that trees with high diameter size classes were selectively exploited and the forest is intermittently recovering through natural regeneration. Unlike Image Forest Reserve, the diameter class >40 cm was found to have the highest number of stems, an indication of protection from illegal harvesting to a large extent and thus sustaining large trees that were illegally harvested by local people for timber and or charcoal.

Wassihun *et al* (2019), pointed out that forest stand density has significant effect on the basal area especially when the tree sizes are almost similar. A single tree stem with larger diameter can have larger basal area than more than a single tree provided the more trees bare smaller diameter than a single tree. This means, the larger number of stems of a particular tree species does not have direct relationship with the basal area, unless they are considered in terms of the same size and number of individuals. Image Forest Reserve trees with the larger DBH had the larger basal area than those with smaller DBH. For the vegetation to have equal basal area it depends on the number of stems with the same diameter, or many stems may lead to having the same BA ($m^2$) with the fewer stems influenced by DBH (cm) size, as opposed to density which relies on the number of stems.

## CONCLUSION

Assessment of trees population structure has been a pre-requisite towards sustainable forest management. It generates an information on the size of trees in a stand in terms of the number and size of individuals in a given forest reserve. The measured DBH of trees in Image Forest Reserve helped to estimate basal area, while the tree stems were useful in determining the density. The basal area provides information on the various sizes of trees and therefore provides the health status of trees in Image Forest Reserve. This can help the TFS to focus their patrols on the areas with tree stem sizes that might be targeted by poachers for timber and charcoal making. The density of trees provides a useful information on the abundance level per hectare in the land cover types in Image Forest Reserve. The reduction in trees density in Image Forest Reserve has an impact on basal area, volume, biomass, above-ground carbon sequesters, and richness. The density and DBH (cm) are somewhat linked to each other as they both contribute to BA $m^2$, even though, they are not directly comparable because of the DBH size effect. This study's observation indicates that Image Forest Reserve hosts relatively high density and many trees have large basal area among land cover types at varying degrees. These findings provide baseline information that will help in conservation strategies of plant resources focusing on the merchantable sizes that might be preferred by illegal loggers. Image Forest Reserve, apart from being under protection faces high disturbance accelerated by illegal activities particularly logging for timber, livestock grazing damage seedlings, branches and leaves of young and short trees as they feed on. Also, wildfires destroy seed bank, seedlings and saplings. Encroachment for agriculture crop farming and settlement at forest edges also disturb natural vegetation biodiversity, and hence calling for the determination of trees density and basal area.

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