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Original Article

Does Tenure Matters? Assessment of Stand Parameters in Ngitili Management System in Meatu District Tanzania

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ABSTRACT

Despite the fact that forests in Ngitili are managed under private and communal tenure regimes, few studies exists that shows how those tenure regimes have influenced forest conditions. The present study assessed stand structure, i.e., diameter and species distribution, basal area, density, and volume in the Ngitili management system under private and communal tenure regimes. A systematic random sampling approach was used to establish circular plots measuring 15 m radius across three Ngitili selected in the study area in which data were collected. R software was used to analyze the collected data sets. Results show that the number of stems (N) basal area (G) and volume (V) per hectare was 3 197.67 stems/ha, 6.92 m2/ha and 36.04 m3, respectively under the private tenure regime. Additionally, N, G and V varied from 572.99 - 1213.73 stems/ha, 5.22 - 6.67 m2/ha and 16.67 - 18.06 m3, respectively in the communal tenure regime. However, diameter distribution of 10 – 20 cm and below 10 cm contributed more to the observed V and N, respectively both in the private and communal tenure regime. Interestingly, diameter distributions showed a negative exponential function of De Liocourt i.e. Inverse J shaped indicating normal trend in an unevenly aged natural forest. On the other hand, the study revealed the Shannon-Wiener diversity Index ranging from 0.99 – 1.88 in communal Ngitili and 1.90 in private Ngitili indicating low species diversity. Generally, N and V in Ngitili under the private tenure regime were better than under the communal tenure regime. However, no significant difference in basal area and tree species diversity was observed between private and communal tenure regimes in Ngitili management systems. The findings presented here can be used in planning the future restoration of degraded ecosystems and for forest management.

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INTRODUCTION

The importance of forest ecosystems in providing direct products (e.g., charcoal, animal fodder, fibre, energy, recreation, biodiversity, carbon storage and flux) and indirect benefits like providing shade, controlling soil erosion, buffering hydrological cycle, and supporting soil fertility cannot be overemphasised (Makaudze, 2013; Mauya et al., 2019; Manyanda et al., 2021; Manyanda & Kashaigili, 2022). The sustainable supply of direct and indirect forest services in Tanzania depends much on the kind of tenure a forest fall into (Kaniki et al., 2012; Manyanda et al., 2020). Forest tenure dictate who can use what forest resources, under what conditions and for how long (Mongo et al., 2014). Tenure, if clearly defined enables local communities to protect the forests and woodlands from encroachment so as to increase their benefits (Mpanda et al., 2011; Mongo et al., 2014). Tanzania mainland is endowed with a forest area of 48.1 million hectares (ha) falling under the five main categories of ownership, namely Village Government, general land, Central Government, Private, and Local Government Authority (URT, 2015; Manyanda et al., 2020). However, forests in Tanzania like most African countries are undergoing considerable change as a result of deforestation and forest degradation attributed by numerous natural and anthropogenic disturbances including poles and timber extraction, fire, firewood collection and charcoal among others (URT, 2015; Sawe et al., 2014; Mauya et al., 2019; Manyanda et al., 2021; Nzyoka et al., 2021).

Deforestation and forest degradation during the post-colonial era in Simiyu, a northern region in Tanzania was driven by tsetse flies and *quellea quelea* birds eradication, agricultural expansion for cash crops and Tanzania's villagisation program (Barrow & Mlenge, 2003; Duguma et al., 2014). These drivers changed the forest stand structures and later, drought and desertification became inevitable threats to the whole region. To reverse the situation, in 1986, with funding from the Norwegian Agency for Development Cooperation (NORAD), the government of Tanzania through the Ministry of Natural Resources and Tourism, in collaboration with the World Agroforestry Centre (ICRAF) introduced the *Hifadhi Ardhi Shinyanga* (HASHI), which is Swahili for the Shinyanga Soil Conservation Programme (Mlenge, 2002; Barrow, 2014). HASHI was a national initiative for the restoration of degraded land, of which the main objectives were to re-green the region and to reverse desertification and aridity (Duguma et al., 2014; Kamwenda, 2002). The program resuscitated a traditional indigenous land management system known as *Ngitili*. *Ngitili is* a local name for dry-season fodder reserves among the Sukuma ethnic tribe in the region (Mlenge, 2004).

Ngitili are initiatives developed by farmers from customary ways of pasturing animals while

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ensuring food security for farmers (Kamwenda, 2002; Duguma et al., 2013; Duguma et al., 2014; Manyanda & Kashaigili, 2022). This system includes preserving an area of trees, grasses, shrubs, and forage during rainy season (Kamwenda, 2002; Barrow, 2014). *Ngitili* encourages trees to be conserved or planted in the land sets aside for grazing in order to overcome shortage of fodder supply in the dry season. Through HASHI, the agropastoralists had the responsibility of conserving and restoring *Ngitili*. The initiation of HASHI programme led to the incorporation of national and international organisations in the process of restoration of degraded land. This was successful because of recognising that the key to the land's restoration are vested in putting local communities at the forefront of these efforts (Duguma et al., 2013; Duguma et al., 2014). Following the efforts, 833 *Ngitili* equivalent to 350,000 hectares had been restored under communal and private tenure regimes across the region by 2004 (Barrow, 2014). The expeditious expansion of *Ngitili* give on to a notable improvement in stand structure in both private and communal-owned *Ngitili* (Kimaro et al., 2011; Minang et al., 2017). Despite the noted expansion of restored *Ngitili*, little has been done on assessing stand structure in *Ngitili* under the private and communal tenure regimes. Notable studies available (Barrow & Mlenge, 2003; Barrow & Shah, 2011; Schuman et al., 2002; Kimaro et al., 2011) revealed the contribution of restored trees in *Ngitili* in risk management for the pastoralist and carbon potential. Others (Kamwenda, 2002; Selemani, 2015) have assessed the contribution of restored *Ngitili* to the livelihoods and soil characteristics.

Furthermore, Manyanda and Kashaigili (2022) revealed the forest cover changes in *Ngitili* under different tenure regimes system using remote sensing and GIS. Therefore, the aim of the present study was to assess stand structure, i.e., tree species and diameter distribution, number of stems, basal area, and volume in *the Ngitili* management system under communal and private tenure regimes. Quantifying stand structure is key in ensuring that forest resources, wildlife, aesthetics, hydrologic recovery, and forage conditions are sustained both for the present and future generations. Additionally, it is very important for projecting vegetation dynamics over time. It is also key for understanding regeneration, mortality, growth, understory development and spread of disturbances (Chen & Bradshaw, 1999, Sawe et al., 2014). Understanding stand structure in the private and communal-owned *Ngitili* would help to make recommendation to the community on the best tenure regimes that could improve forest conditions in the *Ngitili* management system.

MATERIALS AND METHODS

Study Area

The current study was done in the *Ngitili* management system in Meatu District, Simiyu Region Tanzania (Fig. 2). The district has an area of 8,871 km^2 and is situated at the latitude 3^o and 4^o south and longitude 34^{o}8' and 34^o 49' east (URT 1996) within a semi-arid zone. The mean annual precipitation of the district is 600-800 mm/year and occurs mainly in mid-November through mid-May (Manyanda & Kashaigili, 2022). The minimum temperature is 26.8^{o}C while the maximum temperature is 33.6 ^{o}C. Moreover, altitude varies between 1000 and 1500 m above sea level (URT, 1996). The soil types of the study area include ferric *luvisols*, *Acrisols*, vertisols, and chromic *cambisols* (Kamwenda, 2002). The major economic activities in the study area are Agriculture and livestock keeping (Maro, 1995; Manyanda & Kashaigili, 2022). The dominant miombo tree species in the study area includes *Julbernardia*, *Brachystegia*, and *Isoberlinia* (Kimaro et al., 2011) while Acacia wood-lands consist mostly of *Acacia tortilis*, *A. nilotica* and *A. polyacantha*, while other important species in this agropastoral land include *Adansonia digitata* and *Tamarindus indica* (Kamwenda, 1999; Kimaro et al., 2011; Manyanda & Kashaigili, 2022).

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The herbaceous layer that occupies the open spaces suffers from severe livestock grazing pressure (Mlenge, 2004; Duguma et al., 2013). The study area is dominated mostly by the Sukuma ethnic group who are traditionally agropastoralists.

Figure 1: Map of Meatu district

Source : (https://meatudc.go.tz>district- profile)

Data Collection

Sampling Design and Plots Layout

Forest inventory with systematic sampling design was used in which plots were laid systematically in the *Ngitili* selected. The selection of the *Ngitili* was based on the tenure category into which they fall into. The *Ngitili* selected under the communal tenure regime were Mwambegwa and Bulyanaga, while under the private regime was Mussa Sambe *Ngitili*. Transects were laid in the selected *Ngitili* where by the interval between transects was 200 m, while the interval between plots was 100 m (Monela et al., 2004). Concentric circular plots measuring 2, 5, 10 and 15 m radii were established in the laid transects for data collection. Data were collected as follow; in the 5 and 10 m radius subplot, all trees with diameter at breast height (dbh) of 5.0 - 9.9 cm and 10.0 - 19.9 cm respectively were measured while in the outer plot of 15 m measurement was executed for trees with dbh ≥ 20 cm. Both local and scientific names of the tree species were identified. Two sample trees that are close to the plot centre for each plot were randomly selected and height was measured. Lastly, all regenerants i.e., trees with dbh < 5 cm were recorded in the 2 m radius subplot (Malimbwi et al., 1994, Chamshama et al., 2004). All the data used in this study were collected between June and September 2008.

Data Analysis

Data were cleaned to eliminate outliers resulting from recording and measurement errors was done in the spreadsheet prior to importing into R software. Additionally, a checklist of tree and shrub species was also prepared to enable species identification. The file was finally imported into R software for analysis. Computations for basal area ha-1 (G), number of stems (N) and volume (V) was done using protocol established. Development of height–diameter equations were done using sample trees that were measured for height to enable estimations of height of those trees that were not measured for height. Lastly, regenerants were counted and transformed into per ha values (N_{reg}). Forest stand structure, i.e., density, basal area, and volume.

Volume and Basal Area Estimation

We used the allometric equation developed by Malimbwi et al., (1994) (Eq. 2) to provide estimates of volume per tree. The individual tree volume per

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hectare that was estimated was scaled up into per plot and per ha basis. The volume was finally squeezed out based on tenure type, i.e., communal, and private.

$$V_i = 0.0000481 d_i^{2.032} h_i^{0.66} \quad (1)$$

Where: V_i = volume of the ith tree (m³), d_i = Diameter at breast height (1.3) for the ith tree (m), h_i= Total height of the ith tree (m)

On the other hand, basal area (G) was estimated using the dbh for all sample trees recorded in the entire plots. The estimated G for individual tree in the plot was summed up and scaled up into per plot and ha basis. (Philip, 2004). The G per hectare was then expressed based on tenure type, i.e., communal and private. Another parameter computed was density (SPH) (stems/ha).

$$G = \frac{\sum 0.0000785 dbh^2}{plotarea} \quad (2)$$

Index of species Diversity and Dominance

The index of diversity also called Shannon-Wiener index of diversity was used to measure species evenness and richness (abundance). Species diversity index normally increases with the number of species in the community. In practices, the Shannon index of diversity of biological communities is not more than 5.0 (Krebs, 1989). The index was estimated using equation 3 (Kent & Coker, 1992);

$$H = \sum_{i=1}^{s} (p_i \log_a p_i) \quad (3)$$

Where; H is the Shannon diversity index; S is the number of species; p_i is the proportion of individuals i in the sample; Log_a is the logarithm to base a

Diversity indices were calculated for each *Ngitili* studied. The calculations were done to allow comparison of trees species abundance in different forestland tenure regimes underlying the studied *Ngitili*

Furthermore, the index of dominance (C) is a measure of individual's distribution among the species in a given community. It equals the probability of picking at random two organisms of different species (Krebs, 1989). The lowest and greatest species diversity in the community is indicated by the greater and lower the value of the dominance index respectively (Misra, 1989). Therefore, the value of C was estimated for each *Ngitili* using the following formula.

$$C = \sum (\frac{k_i}{M})^2 \quad (4)$$

Where; C is the index of dominance, M is the number of individuals (all species) in the sample and Ki is the number of individuals of species i in the sample

Comparison of Stocking Parameters between Private and Communal Tenure

We applied a two-way analysis of variance (ANOVA) by applying Duncan's multiple range test for the ratio to find out the mean volume, number of stems, basal area and species diversity which are different between private and communal *Ngitili*. Consequently, the calculated t-values with respective probabilities were compared with the tabulated p-value ($p<0.05$) to see whether there are statistically significant differences in the stand parameters between private and communal *Ngitili*.

RESULTS

Stocking Parameters in *Ngitili* Under Communal Tenure Regime

Under this category, Bulyanaga and Mwambegwa communal *Ngitili* were considered in assessing stand structure, i.e., number of stems per hectare, basal area per hectare and volume per hectare. *Table 1* shows the results of stocking parameters in *Ngitili* of Bulyanaga and Mwambegwa.

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Table 1: Stand structure in Ngitili under different tenure types

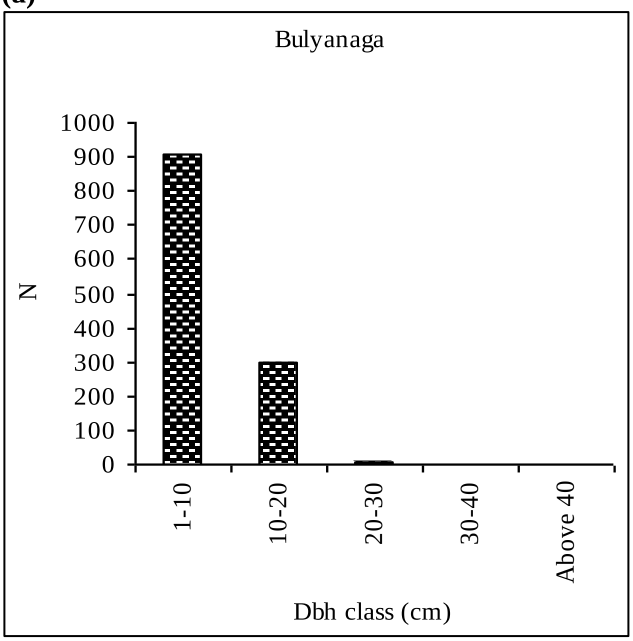
			Stand parameters		
S/No.	**Ngitili name**	**Tenure types**	**N (stems/ha)**	**G (BA/ha)**	**V (M^3/ha)**
1	Bulyanaga	Communal	1,213.73[a]	6.67[a]	18.06[a]
2	Mwambegwa	Communal	572.99[a]	5.22[a]	16.67[a]
3	Mussa Sambe	Private	3,197.67[ab]	6.92[a]	36.04[ab]

Note: Stand parameters having same superscript between tenure types aren't significantly different at $p < 0.05$.

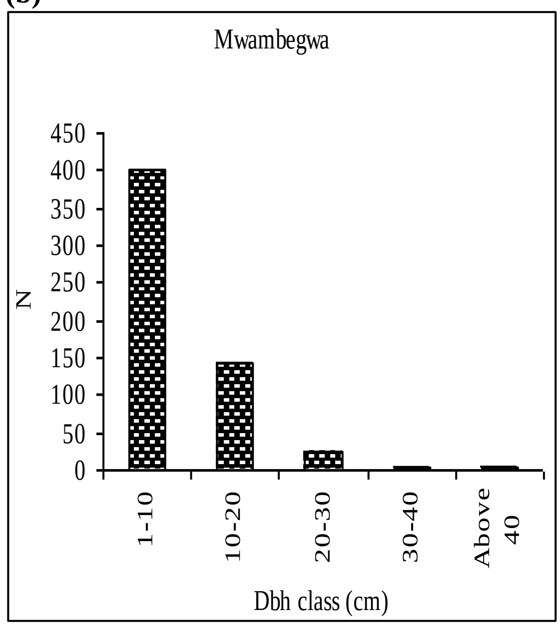
Table 1 indicates the average number of stems/hectare in Bulyanaga and Mwambegwa *Ngitili* as 1 213.73 and 572.99 stems per hectare, respectively, while the basal area for the Bulyanaga and Mwambegwa *Ngitili* were 6.67 and 5.22 m^2/ha respectively. Additionally, the volume was 18.6 and 16.67 m^3/ha for the *Ngitili* of Bulyanaga and Mwambegwa, respectively. Moreover, diameter distributions in the two *Ngitili* were alike to those of uneven-aged stands in which diameter distribution were decreasing constantly towards the larger classes (*Figure 2a, b, c,* and d). There were rather many small and few large individual trees in these *Ngitili*.

Figure 2: Stand structure (N (stems/ha), G (m^2/ha) and V (m^3/ha)) against Dbh distribution in Bulyanaga and Mwambegwa Ngitili

(a)



(b)



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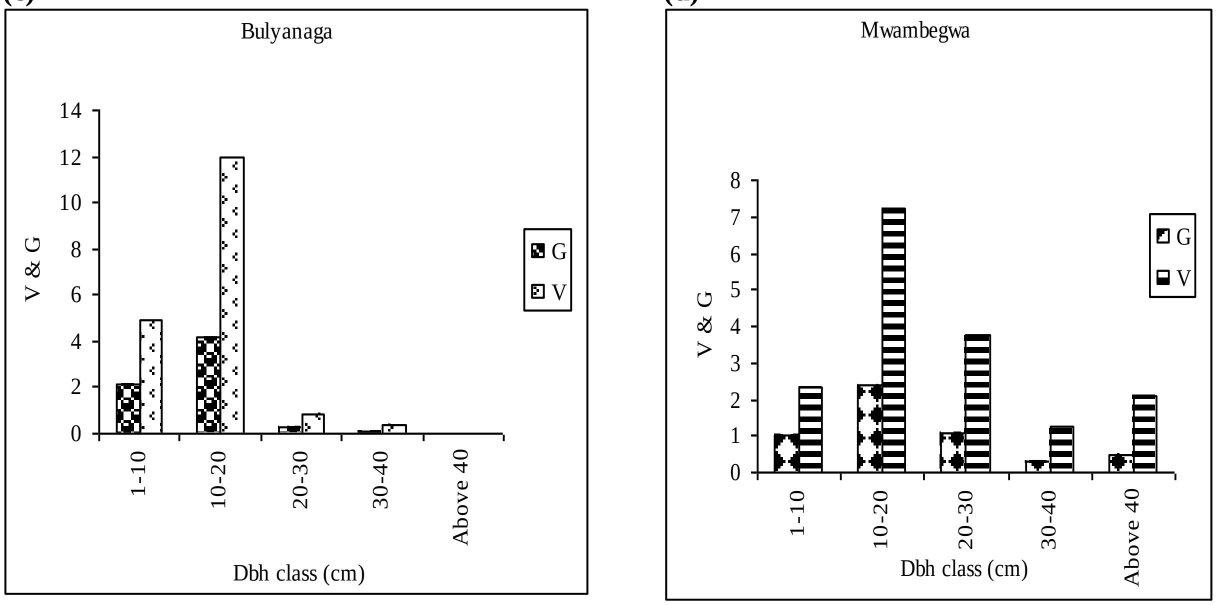
(c) (d)

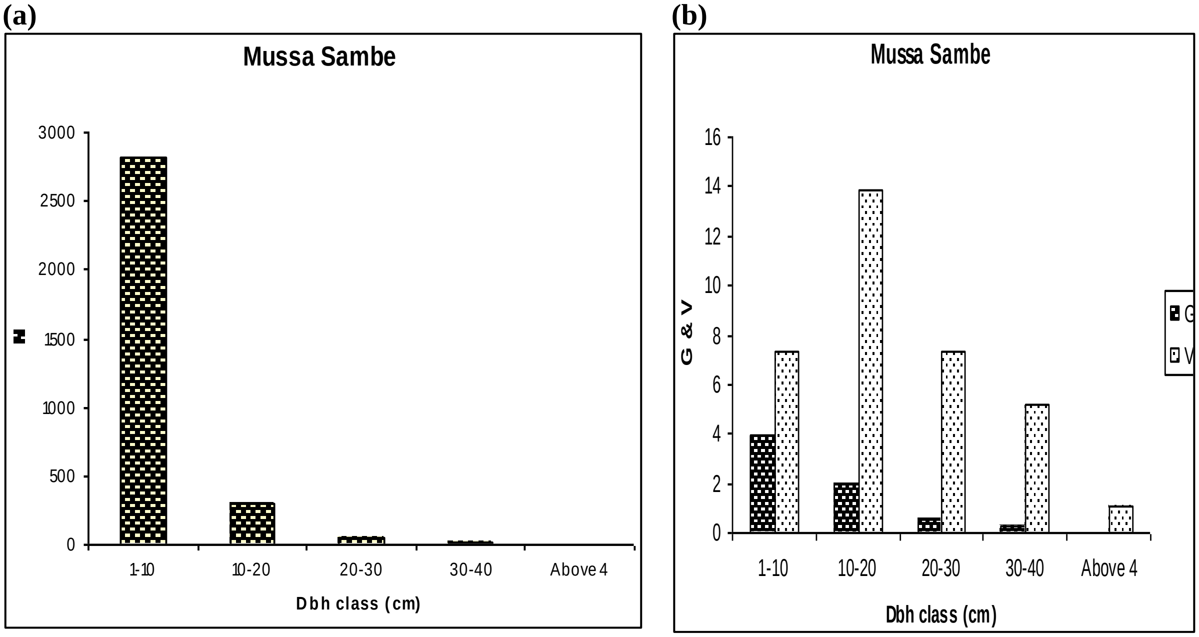


Stand Structure in the Private Tenure *Ngitili*

Under this category, Mussa Sambe *Ngitili* was considered in assessing stand structure. *Table 2* indicates the average N, G and V per hectare as 3 197.67, 6.92 m^2/ha and 36.04 m^2/ha, respectively. The diameter class was presented against N, G and V to indicate the contribution of Dbh to other stand structures (*Figure 3*). Results indicate that the Dbh class of 1-10 cm contributed more to N and G, while Dbh of 10 – 20 cm contributed more to V.

Figure 3: Stocking parameters distribution in private Ngitili of Mussa Sambe

(a) (b)



Tree species Diversity and Dominance between Communal and Private *Ngitili*

Tree species diversity also called Shannon-Wiener Index of Diversity (H) and species dominance (C)

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between communal and private *Ngitili* are shown in *Table 3*. The study revealed the H value of 1.88 and 0.99 in the Bulyanaga and Mwambegwa *Ngitili*, respectively that are under the communal, while it showed the H value of 1.90 for the *Ngitili* of Mussa Sambe which is under private. On the other hand, the C value of 0.17, 0.41, and 0.21 was found in the *Ngitili* of Mwambegwa, Bulyanaga and Mussa Sambe, respectively.

Table 2: Shannon winner index of diversity (H) and index of dominance (C) between communal and private Ngitili

Ngitili name	Tenure types	Shannon Winner Index of Diversity (H')	Index of dominance (C)
Bulyanaga	Communal	1.88^a	0.27^a
Mwambegwa	Communal	0.99^a	0.41^a
Mussa Sambe	Private	1.90^a	0.21^a

Note: Shannon Winner Index of diversity and Index of dominance having the same superscript letters between tenure types aren't significantly different at $p < 0.05$.

DISCUSSION

Stand Structure in *Ngitili* Under Communal Tenure Regime

The numbers of stems per hectare (N) followed the trend of reversed J-shaped with observable high number of trees with Dbh below 10 cm. The dominance of small trees suggests that regeneration is taking place continuously and external disturbances are limited (Teketay et al., 2018; Tesfaye et al., 2010; Gebeyehu et al., 2019). The tenure regime underlying this *Ngitili* in which people surrounding these *Ngitili* are not allowed to harvest small trees of Dbh below 10 cm provides further support for that proposition. The N found in these *Ngitili* are in line with those reported by other studies done elsewhere in Miombo Woodlands. For instance, Chidumayo (1993) obtained N value of 750 per hectare for miombo woodland in Zambia. Malaise (1978) reported a range of 520 to 645 N value in miombo woodland in Katanga (DRC). Njana (2008) and Ngowi (2008) reported the N value of 583 and 510 in the Miombo Woodlands of Urumwa and Kimani in Tanzania.

Furthermore, the average volume (V) and basal area per hectare (G) in Bulyanaga *Ngitili* were 18.06 m^3/ha and 6.67 m^2/ha, respectively. While in Mwambegwa, *Ngitili* was 16.67 m^3 and 5.22 m^2/ha, respectively. The pattern (*Figure 2*) followed the normal inverse J-shaped which is the normal expectation in an undisturbed natural forests. The distribution indicates that trees with Dbh ranging from 1 to 20 cm account more to V and G compared to trees with Dbh > 20 cm. The value of V and G revealed in Mwambegwa and Bulyanaga Ngitili are similar to those found in other studies. Monela et al. (2004) reported volume per hectare ranging from 6.623 to 27.022 m^3 ha^{-1} in *Ngitili* of Shinyanga region. However, they are much lower than those found in miombo woodland of mixed age and species ranging from 39 to 76 m^3 ha^{-1} (Chamshama et al., 2004). This is because of the lowest species diversity reported in these *Ngitili* as compared to other studies.

Stand Structure in the Private *Ngitili*

Under this category, Mussa Sambe *Ngitili* was considered in assessing stand structure in the private *Ngitili*. The diameter class distribution of trees in *Ngitili* under this category confirms De iocourt's q-factor procedure i.e. inverse J-distribution, with stem density decreasing with an increase in Dbh (*Figure 1*). The figure shows that forest regeneration in *Ngitili* is present. Observing very critically at the *Ngitili*, the histogram indicates an exponential reduction in the stems density for diameter class above 10cm dbh. This was probably

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due to the harvesting of large trees in this regime. Additionally, the volume and basal area per hectare were 36.04 m^3/ha and 6.92 m^2/ha, respectively in the Mussa Sambe *Ngitili*. Interestingly, while trees with Dbh ranging from 1 to 10 cm account for more G, trees of the Dbh of 10-20 cm contribute more to volume per hectare. This suggests that the *Ngitili* is managed more for the production of timber than poles and firewood.

Moreover, the N and V values found in the private *Ngitili* is much greater than that found in communal *Ngitili*. This is because there is relatively little harvesting pressure of trees, presumably for firewood collection, charcoal making and brick making in the private *Ngitili* compared to communal *Ngitili*. In addition, more stems in the private tenure regime were attributed due to the fact that one has more freedom in managing private *Ngitili* than participating in the management of communal *Ngitili* because interests and commitments to their management may differ (Bernardol, 2009). Interestingly, the number of stems found in the private *Ngitili* conforms to those found in the study by Monela et al. (2004) who found 3 232, 2 508, 2 958 and 2 602, number of stems per hectare in *Ngitili* of Shinyanga Rural, Bukombe, Bariadi and Maswa, districts of Shinyanga and Simiyu regions Tanzania.

Tree Species Diversity and Index of Dominance between Communal and Private Ngitili

Tree species Diversity also named Shannon-Wiener Index of diversity (H) shows species richness i.e. number of species and evenness i.e. species distribution in both private and communal regimes (Magurran, 1998). The greater the species diversity is indicated by the larger value of H and vice versa. Moreover, an ecosystem with an H value greater than 2 is considered to have medium to high species diverse (Giriba et al., 2011; Gonçalves et al., 2017). Thus, *Ngitili* in Meatu district in both private and communal tenure regimes have a lower tree and species diversity. However, private *Ngitili* is more diverse compared to communal *Ngitili*. Species found to contribute to the observed species diversity in both communal and private *Ngitili* included: *Acacia tortilis*, *Dichrostchys cinerea*, *Acacia Senegal, Acacia nilotica, Acacia polycantha, Luceana lucocephala, Delonix procera, Azandirachta indica, Senna siamea, Acacia drepanolobium, Kadaba adenotricha, Dichrostchys cinerea, Kigeria africana and Diospyros fischeri*. Comparative studies elsewhere in Miombo Woodlands have consistently shown more or less the same value. For example, Monela et al. (2004) reported the H value of *Ngitili* woodland ranging from 1.874 to 3.669 in all the districts of Shinyanga region, Tanzania.

Regarding species dominance (C), the larger the C value the lower the species diversity and the vice versa is true taking into consideration a scale of 0 - 1 (Misra, 1989). The present study showed C value of 0.27 and 0.41 for Bulyanaga and Mwambegwa *Ngitili*, respectively, while the C value of 0.21 was revealed in Mussa Sambe *Ngitili*. These indicate that there is lower species richness in communal *Ngitili* as compared to private *Ngitili*. Furthermore, all *Ngitili* in both communal and private tenure regimes were dominated by Acacia species, i.e., *Acacia polycantha*, *Acacia tortilis*, *Acacia seyal* and *Acacia drepanolobium*. These *Acacias* are pioneer species, i.e., species that are the first to colonise degraded areas (Bernardol, 2009). Also, the occupancy of Acacia species in the *Ngitili* studied suggests that the woodlands are recovering (Bernardol, 2009). However, it has been observed that *Acacia* species such as *Acacia polycantha, A. nilotica* and *A. tortilis* are important species known in the region for animal browsing (Mlenge, 2002; Bernardol, 2009). This suggests that the owner of *Ngitili* promote these tree species when they are restoring degraded *Ngitili* because they would be used for animal browsing.

The C values in this study are in agreement with what has been found in another study in Miombo Woodlands elsewhere in Tanzania. Mafupa (2006)

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reported a C value of 0.135 in the Igombe river forest reserve, Tanzania. Additionally, Monela et al. (2004) reported C values of 0.108, 0.106, 0.164 and 0.292 for Bariadi, Maswa, and Meatu and Shinyanga Urban Districts of Shinyanga region, Tanzania, respectively. Furthermore, Malimbwi and Mugasha, (2001) reported a C value of 0.085 for the miombo woodland in the Mkindo forest reserve in Morogoro rural district, Tanzania. On the other hand, Zahabu (2001) revealed the C values of 0.092 and 0.065 for miombo woodland in the public lands and reserved forests, respectively at Kitulangalo, Morogoro region. The C values reported in the present study for forests in Ngitili suggests lower species richness compared to other forests in the Morogoro region of Tanzania.

CONCLUSION

Stand structure i.e. species distribution, N, G, V, and diameter distribution were thoroughly studied in both the communal and private tenure regimes. The N and V were higher in the private *Ngitili* than in the communal *Ngitili*. This indicates that the private tenure regime had a better strategy in managing *Ngitili* compared to communal *Ngitili*. Moreover, no significant difference in basal area and tree species diversity was observed between private and communal tenure regimes in *Ngitili* management systems. The diameter distributions showed a negative exponential function of De Liocourt (Inverse J shaped). In order to ensure sustainable harvesting from these well-restored *Ngitili* therefore, the livelihoods search should be done sustainably to prevent degradation of the *Ngitili* ecosystem. Additionally, for the restoration of degraded land elsewhere in Tanzania both communal and private approaches should be used, but more emphasis should be given to the private regime approach.

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