CHAPTER 7

DISTRIBUTION, POPULATION STRUCTURE AND CARBON STORAGE OF BAMBOO SPECIES IN TANZANIA

Evaristus Aloyce, Bernardol J. Manyanda, Samora A. Macrice, Wilson A. Mugasha and Rogers E. Malimbwi

Abstract

Sustainable management of forest resources requires information regarding quantities and quality of the resources. Despite this fact, the existing information for bamboo forest resources in Tanzania regarding abundance, distribution along altitudinal ranges, density, basal areas and carbon stocks is inadequate, site specific and fragmented. Based on 696 plots out of 30 773 plots surveyed by the National Forest Resources Assessment and Monitoring (NAFORMA), the present study assessed the distribution, abundance and carbon storage of bamboo species in Tanzania in R software. Results indicates that, 11 bamboo species from five genera and two tribes were recorded in Tanzania. They are dominated by *Arundinaria alpina* and *Oxytenanthera abyssinica* that constitutes 55.9% of the total bamboo population and are distributed in only 11 administrative regions of the country. They occur at altitude of 76 m.a.s.l to 2592 m.a.s.l, whereby about 85.2% of bamboo population are distributed below 1500 m.a.s.l. Moreover, bamboo occurs more abundantly in woodland (66%) and least in open land (0.1%). Similarly, most of the bamboo is in the production forests (44.7%) followed by Agriculture land (19.5%) while wetlands have the least (0.4%). Results further indicates that bamboo species have a mean stocking, basal area and carbon stocks of 2460 culms/ha, 2.391 m^2/ha and 1.566 tC/ha respectively. Since most of the carbon is stored by *Arundinaria alpina* and *Oxytenanthera abyssinica* that contributes 58.2% of the total carbon stored by bamboo species in the country, efforts should be strengthened to manage these species. Likewise, for mitigating climate change bamboo species should be planted in altitude below 1500 m a.s.l. Due to lack of bamboo allometric biomass models in Tanzania, the models used in this study was borrowed from Kenya and Ethiopia, indicating the need to develop such models for Tanzanian bamboo.

Key words: Distribution, Bamboo species, carbon, population structure

Introduction

Bamboo is an ancient woody grass widely distributed in tropical, subtropical and temperate regions (Liese and Köhl, 2015). Globally, they are distributed between 47°S and 50° 30'N latitude and from sea level to 4300 m a.s.l (Liese and Köhl, 2015). They are naturally distributed in Asia, Latin America and Africa (BPG, 2012; Liese and Köhl, 2015). Their distribution in tropical Asia, is concentrated in China, India, Japan, Myanmar and Malaysia (FAO, 2007; Liese and Köhl, 2015). Unlike in other continents where they are indigenous, they have been introduced in Europe and Australia (Liese and Köhl, 2015).

In Africa, they grow naturally in Benin, Burundi, Sudan, Cameroon, Eritrea, Ethiopia, Ghana, Liberia, Kenya, Malawi, Madagascar, Mozambique, Nigeria, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Angola, Gabon, Comoro Islands and Zambia (Liese and Köhl, 2015; Masau, 2016). Furthermore, 89.6% of all bamboo population in Africa are distributed in Nigeria, Ethiopia and Senegal (FAO, 2010). Bamboo consists of 1642 species that includes 1521 woody bamboo and 121 herbaceous bamboos (Vorontsova *et. al*., 2016). Out of these, only five species grow naturally in Africa i.e. *Arundinaria alpina, Hickelia africana, Oxytenanthera abyssinica, Oreobambos buchwaldii* and *Thamnocalamus tessellatus* (Bystriakova *et. al*., 2004; Bystriakova and Kapos, 2006; Vorontsova *et. al*., 2016). Despite the low diversity of bamboo in Africa, two naturally grown species i.e. *Thamnocalamus tessellatus* and *Hickelia africana* are under the International Union for Conservation of Nature (IUCN) red list categorized as “critically endangered species” (IUCN, 2013).

Tanzania unlike other African countries has the highest richness of bamboo species with four naturally growing species i.e. *Arundinaria alpina, Hickelia africana, Oxytenanthera abyssinica* and *Oreobambos buchwaldii* (Bystriakova *et. al*., 2004; FAO, 2007; Vorontsova *et al*., 2016). They are distributed in two ecological zones of lowland and high rainfall natural forests that includes forests in the Eastern Arc Mountains, Southern and Northern parts of the country and Southern highlands (Lovett, 1994; MNRT, 2000; FAO, 2007). These include administrative regions of Arusha, Mbeya, Iringa, Morogoro, Lindi, Kigoma, Coastal, Ruvuma, Rukwa, Tanga and Kagera (Chihongo *et. al*., 2000). They cover an estimated area of 127 824 ha, equivalent to 0.27% of the total forest land area of 48.1ha million in Tanzania (Chihongo *et. al*., 2000; MNRT, 2015).

Bamboos are among the most versatile and widely utilized plants in the world (FAO, 2007; Liese and Köhl, 2015). They comprise of over 1500 documented uses worldwide and thus regarded as the most multipurpose plants in the world (Liese and Köhl, 2015). The uses of bamboo had shifted from low-end craft and utensils (handcraft, construction, weaving, production of bamboo wine, furniture, basketry, grain storage huts, and residential fencing) to high-end value added commodities (limited panel, boards, pulp, paper, mats, fabricated houses, cloth, bio-fuel energy, artistic carvings and many others) (Chihongo *et. al.*, 2000). Moreover, bamboo contribute significantly to climate change mitigation due to high rate of carbon sequestration and storage that is largely influenced by specie’s type, climatic conditions, soil type and management practice (Song *et. al*., 2011; Mishra *et. al.,* 2014, Yuen *et. al*., 2017).

Despite their potentials, anthropogenic activities like expansion of farms, livestock grazing, fire and its high commercial uses pose challenges to their conservation (Chihongo *et al*., 2000; Dutta and Devi, 2013; MNRT, 2015). These activities cause change in their distribution pattern, population structure and carbon storage (Dutta and Devi, 2013). The changes are anticipated to be different in land use types, ownership types, administrative regions, altitudinal ranges and species types. This is because of the different management approaches, species extraction preferences and altitudinal differences. Sustainable management of forest resources requires information regarding quantities and quality of the resources (MNRT, 2015). Despite this fact, the existing information for bamboo in Tanzania regarding abundance, distribution, altitudinal ranges, density, basal areas and carbon stocks is inadequate, and fragmented (Chihongo *et. al*., 2000; FAO, 2007). Tanzania conducted her first ever National Forest Inventories (NFI) popularly known as National Forest Resources Assessment and Monitoring (NAFORMA) between 2009 and 2014. Taking the advantages of NAFORMA data sets, this study aimed at assessing the distribution, abundance and carbon storage of bamboo species in Tanzania. The findings of this research would provide information on the potential of bamboo in carbon storage as well as information on the distribution and abundance that would be used to improve sustainable management of bamboo. Such information is also important for the ongoing REDD+ reporting activities as well as for conventional objectives related with sustainable forest management.

Materials and methods

Study area

The United Republic of Tanzania is a union of Mainland Tanzania and Zanzibar, it is located between longitude 29° and 41° East and Latitude 1° and 12° South. NAFORMA data were collected from Tanzania mainland. Tanzania mainland is endowed with a wide range of natural resources. The country has a very diverse climate, depending on altitude and latitude. The rainfall distribution tends to vary from year to year and place to place. The mean annual rainfall varies from below 500 to over 2000 mm per annum. The rainfall for the large part of the country is bimodal with short rains from October to December and long rains from March to May.

Data collection

Sampling design

This study used data collected by the NAFORMA. NAFORMA sampling design adopts a two-phase stratified systematic cluster sampling with optimal allocation of plots in the cluster (Tomppo *et. al.* 2014; MNRT, 2015). The first-phase sample consists of clusters of plots laid on a 5 × 5 km grid over mainland Tanzania. The first-phase clusters were stratified based on a combination of three criteria namely; predicted growing stock, time consumption for cluster measurements and slope of the terrain. At national level, the three criteria were used to assign the first-phase clusters into 18 pre-defined strata (Tomppo *et. al.,* 2014). Within each stratum, second-phase samples of clusters were selected using optimal allocation with cost functions tailored for each stratum using a simulation approach described in Tomppo *et. al., (*2010). Consequently, greater sampling intensity was allocated to strata with more variation and larger predicted growing stock and less sampling intensity to strata with less variation and smaller predicted growing stock. Circular plots of 15 m radius laid out in clusters. The number of plots in a cluster were either 6, 8, or 10 depending on accessibility and the distance between plot centers within a cluster was 250 m (Figure 7.1).

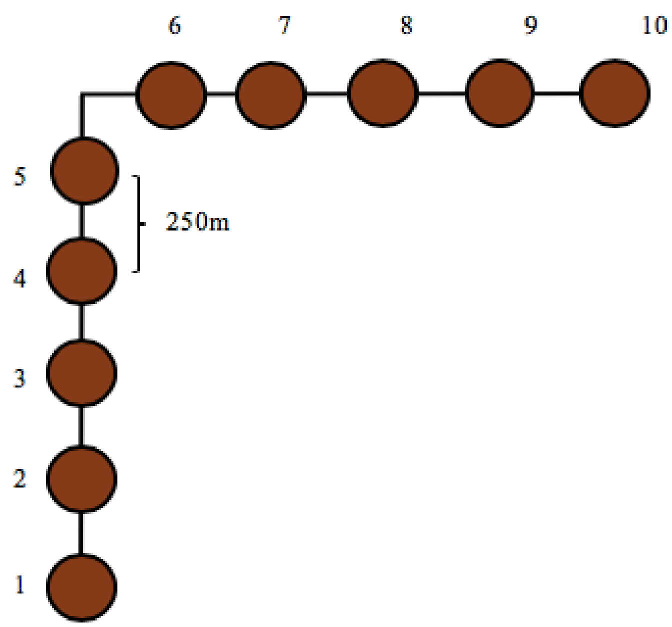

Figure 7.1. NAFORMA cluster and plots design (MNRT, 2010)

Data collection

Bamboos present in the plots were measured on average diameter at breast height (DBH), average height, number culm/stems in the plot and its names were identified. In addition, vegetation type, land use, ownership, land cover, altitude, plot center coordinates and cover were recorded.

Data extraction

Data was extracted from the NAFORMA database server located at Sokoine University of Agriculture (SUA). The whole NAFORMA data set was imported to R software for the extraction of bamboo data and their related cluster and plot information. Extraction of the data was done by performing Structured Query Language (SQL) queries within R software using "sqldf" package. The extracted data sets were subjected to validation, cleaning in order to remove outliers (Son, 2011).

Data analysis

Distribution of bamboo species along altitudinal gradient, across vegetation types and land uses

The distribution was assessed by presence/absence data (Whittaker, 1972) of the bamboo species along the altitudinal gradient, across vegetation types and land uses. The altitudinal band of the 200 m band was adopted for this study. Samples within each altitudinal band were pooled and the number of species observed in each band was regarded as richness (Whittaker, 1972; Shimada and Wilson, 1985). A relative abundance of bamboo species in various vegetation types was calculated as the ratio of the number of species found in each vegetation type and the total number of species recorded in all study vegetation types which is according to May (1975), as cited by Magurran (1988).

$$ni = \frac{N_T}{S}\sum_{n=i}^{S}\left(\frac{1}{n}\right) \qquad (1)$$

Whereby: n_i the abundance of the i^{th} species, N_T is the total number of individuals and S is the total number of species. Stand density (culm/hectare) was determined based by the formula of Philip, (2004).

$$N = \frac{\Sigma\left[\frac{ni}{ai}\right]}{n} \qquad (2)$$

Whereby; N is the number of stems per hectare, n_i counts in i_{th} plots, a_i is the area of the of i_{th} plots in hectares, n is the total number of sample plots.

Likewise, basal area (G) was computed from the DBH for all bamboo across the entire plots. The basal area for all trees in the plot was summed up and divided by the size of the plot to get basal area per hectare (Philip, 2004).

$$G = \frac{\sum(0.0000785 \times DBH_i^2)}{a} \qquad (3)$$

Whereby: G is the basal area per ha, DBH is diameter at breast height of tree i in n^{th} plot; and a is a plot area

Estimating above and belowground carbon stocks for bamboo species

Aboveground carbon (AGC) stocks was estimated from allometric models that estimate biomass. Since there is no allometric model developed for bamboo in Tanzania, a general allometric models for estimating AGB in bamboo species developed in Kenya was used (Kinyanjui *et. al*., 2014).

$$AGB = 1.04 + 0.06 \times [\text{DBH} \times -1.11 + 0.36 \times (\text{DBH})^2] \quad (4)$$

Whereby: AGB is aboveground biomass.

The model covers a wide range of aspects such as range of diameter and height, bamboo species included, tree density and species geographical range (Walker *et. al*., 2016). Additionally, AGC was estimated by the equation 5:

$$AGC=AGB \times CF \quad (5)$$

Whereby; AGC is above ground carbon; AGB is above ground biomass and CF is carbon fraction. Many authors found that, the CF range between 45% and 49% of the dry wood biomass. (Brown, 1989; MacDicken, 1997; Djomo *et. al.,* 2010; Vashum and Jayakumar, 2012; IPCC, 2006). In this study, we used CF of 0.47 (IPCC, 2006).

On the other hand, belowground biomass (BGB) of each culm/stem was estimated by multiplying AGB with 0.27 as the root/shoot ratio for bamboo species (Moges *et. al*., 2010). The BGC was finally obtained with the use of equation 6;

$$BGC=BGB \times CF \quad (6)$$

Whereby; BGC is belowground carbon, BGB is below ground biomass and CF is carbon fraction.

Results

Spatial distribution of bamboo species according to regions and altitudinal ranges

Figure 7. 2 and 7.3 present percentage distribution of bamboo species across regions and their spatial distribution across country. Across regions, high distribution was found in Lindi region followed by Ruvuma, Mtwara, Iringa, Njombe and Kigoma, while Tanga was the least. The distribution was confined in only eleven administrative regions (Figure 7.2). Figure 7.4 indicates the distribution based on altitudes. Most of bamboo species are mostly distributed in low altitudes below 1500 m.a.s.l.. Moreover, findings revealed an increasing trend in total species richness from 76 m.a.s.l to 500 m. a. s. l. followed by decrease in richness from 500 m.a.s.l to 2600 m.a.s.l. Thus, the high bamboo species richness in Tanzania is found between 400 m.a.s.l and 800 m.a.s.l with a maximum value at 500 m.a.s.l.

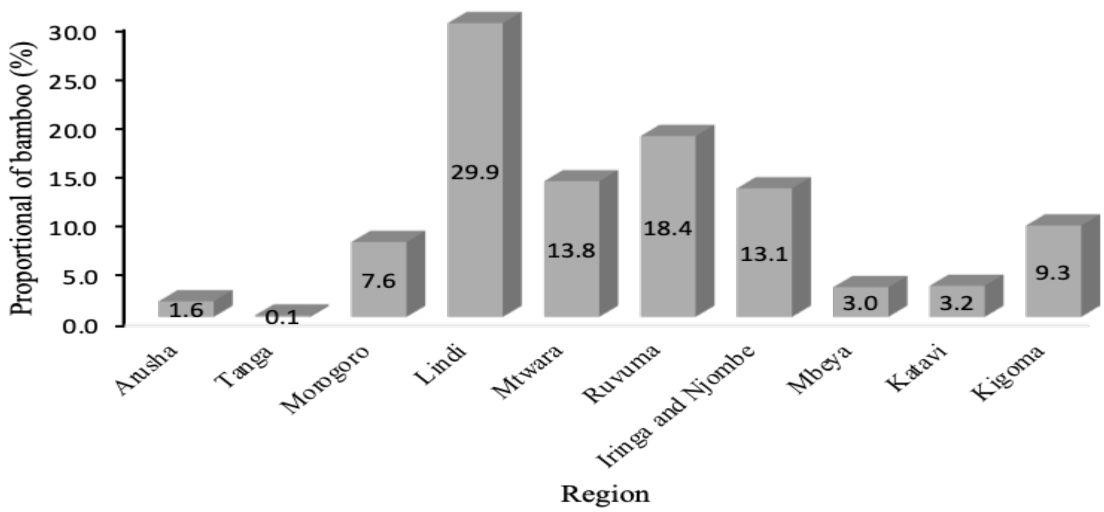

Figure 7.2. The distribution of bamboo species across regions in Tanzania

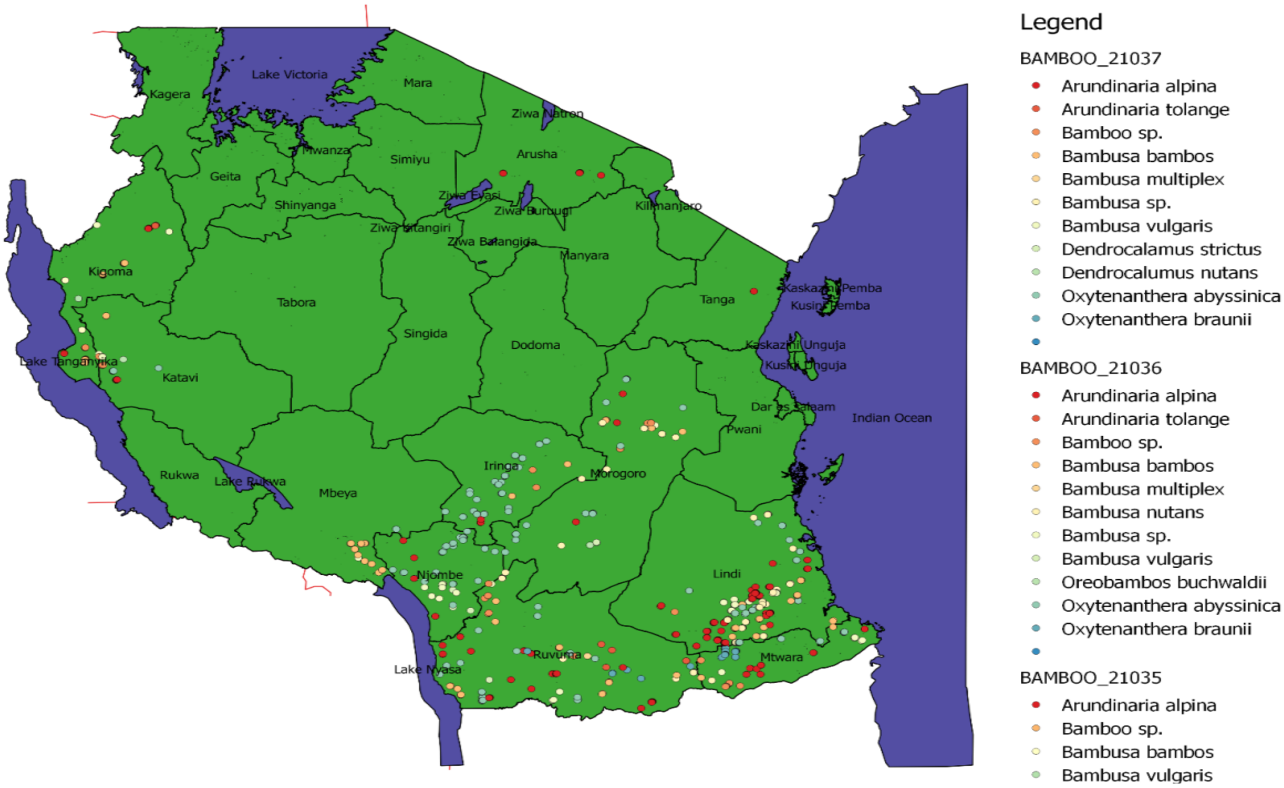

Figure 7.3. A Map of bamboo species distribution according to regions in Tanzania

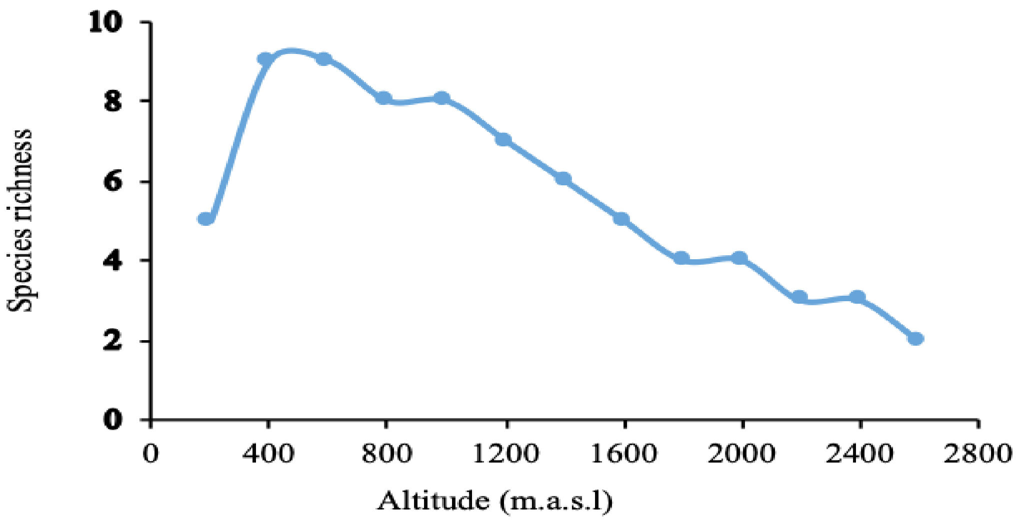

Figure 7.4. Bamboo species richness along altitudinal range

Distribution, density, basal area and carbon stocks

Table 7.1 shows the relative abundance, density, basal area and carbon stocks of bamboo species in Tanzania. *Oxytenanthera abyssinica* was the most abundant bamboo species followed by *Arundinaria alpine*, *Bambusa bambos*, *Bambusa spp.* while *Dendrocalamus nutans* and *Oreobambos buchwaldii* were distributed in few areas across the country. In terms of density, *Bamboo spp*. had higher number of culms (3622 culms/ha) followed by *Bambusa nutans* (3211 culms/ha), *Bambusa multiplex* (3012 culms/ha), *Oreobambos buchwaldii* (2972 culms/ha)while *Bambusa vulgaris* (1247 culms/ha) the least distributed. In terms of basal area per hectare, *Bambusa multiplex* had higher basal area per hectare followed by *Dendrocalamus strictus*, *Bambusa nutans*, *Bamboo spp*., *Bambusa bambos* while *Bambusa vulgaris* had least basal area per hectare. Regarding AGC and BGC, *Bamboo spp*., had higher AGC followed by *Bambusa nutas*, *Bambusa multiplex* while *Bambusa vulgaris* had least AGC per hectare.

Table 7.1. Abundance, density, basal area, carbon stocks and altitudinal ranges of bamboo species in Tanzania

Species name	Abundance	Density (culms/ha)	Basal area (m^2/ha)	AGC (tC/ha)	BGC (tC/ha)	Altitude (m.a.s.l)
Bamboo spp.	0.069	3622	3.297	1.825	0.493	211- 1920
Bambusa nutans	0.010	3211	3.417	1.649	0.445	393- 9170
Bambusa multiplex	0.003	3029	5.251	1.722	0.465	908 -1063
Oreobambos buchwaldii	0.001	2972	1.233	1.390	0.375	1531
Bambusa spp.	0.129	2852	1.381	1.366	0.369	108 -1936
Oxytenanthera abyssinica	0.287	2790	1.732	1.081	0.292	93 - 2311
Arundinaria alpina	0.272	2656	1.428	1.239	0.335	76 - 2592
Dendrocalamus strictus	0.006	2519	3.428	1.349	0.364	698 - 9060
Bambusa bambos	0.165	2368	3.206	1.320	0.356	100 - 2418
Dendrocalamus nutans	0.001	1996	1.392	0.970	0.262	670
Bambusa vulgaris	0.056	1247	0.532	0.590	0.159	138 - 1749

Bamboo species richness and density across ownership and land use types

Table 7.2. shows the distributed of bamboo species in different land use types. In terms of density, bamboo species was found in decreasing order as follows: production, wildlife reserves, shifting cultivation, protection forest, agriculture, grazing land, and built up areas. Similarly, production forest had the highest species richness compared to other land use types. Based on ownership types (Table 7.3), there were higher density in village land, followed by general land, central government, local government and private land. In terms of species richness, village land had higher species richness followed by general land, central government and private land, and local government land.

Table 7.2. Area, species richness and density of bamboo species in Tanzania

Land use types	Area covered (Ha),000	% area covered	Species richness	Density (culms/ha)
Other land	9.315	0.9	3	5265
Production forest	458.189	44.7	11	2898
Wildlife reserve	118.903	11.6	4	2634
Shifting cultivation	116.854	11.4	6	2263
Protection forest	98.403	9.6	7	2000
Agriculture	199.881	19.5	6	1776
Grazing land	3.075	0.3	2	1189
Water bodies/Swamps	4.100	0.4	1	1095
Built up areas	16.401	1.6	1	525
Total	1025.121	100		19645

Table 7.3. Area, number of species and density of bamboo species under ownership types in Tanzania

Ownership types	Area covered (Ha),000	% area covered	Species richness	Density (culms/ha)
Village land	479.757	46.8	10	2870
General land	58.432	5.7	8	2703
Central Government	154.793	15.1	8	2665
Local Government	60.482	5.9	5	2323
Private	269.607	26.3	8	1598
Others	2.050	0.2	1	424
Total	1025.121	100		12583

Discussion

This study identified three indigenous species and eight exotic species across Tanzania mainland. These results contradict with other studies (Kigomo, 1988; Chihongo *et. al.,* 2000; Bystriakova *et. al.,* 2004; FAO, 2007; Oyen, 2011) which reported, four indigenous bamboo species existing in Tanzania. The difference in the species richness could be attributed by differences in the sampling design, species extinction and most importantly, two species were introduced after the previously studies. Furthermore, the absence of *Hickelia africana* in this study could be due low inclusion probability or even to species extinction (IUCN, 2013). In terms of regions, Lindi region accounts for higher species richness followed by Ruvuma and Mtwara regions, while Tanga region is the least. These results contradict with the study by Kigomo (1988) and Chihongo *et.al.* (2000) who reported that bamboo species are mostly found in Arusha followed by Tanga, Morogoro, Iringa, Mbeya, Lindi, Ruvuma, Kigoma, Kilimanjaro, Coastal and Kagera regions. Although there is possibility of low inclusion probability, the NAFORMA data covered the entire country while most of the past studies were fragmented. We are therefore tempted to trust more the current findings. This study revealed further that no bamboo species exist in Coastal and Kagera regions as reported before. Similarly, the proportion of species distribution found in the present study and that found previous study in these regions differs. This could be explained by high commercial values attached to them that cause to be extracted in large quantity.

On the other hand, altitudinal range is the key factor which affect bamboo distribution across the country. Most of bamboo species (85.2%) in Tanzania are found in low altitudes (below 1500m.a.m.s.l). This is in line with other studies (Seethalakshmi and Kumar, 1998; Judziewicz *et. al.,* 1999; BPG, 2012). Nevertheles, *Arundinaria alpina* is distributed in a wide altitudinal range between 76 m.a.s.l and 2592 m.a.s.l. Similar trend was also reported byKigomo, (1988), Ohrnberger (1992), and Mbuya *et. al.* (1994). There were differences in stocking and species performance in terms of stocking and size for the two clusters of altitudinal ranges. Stocking in upper cluster was higher compared to lower cluster. This suggests that *Arundinaria alpina* grows well at high altitude compared to low altitude.

This is further explained by the fact that the species is a member of tribe Arundinarieae, which is widely distributed in high altitude (Judziewicz *et. al.,* 1999). *Bambusa bambos* are distributed highly in low altitude with an altitudinal range of 100 to 1300 m.a.s.l with stocking 2400 culms/ha and in higher altitude (1800 to 2418 m.a.s.l) with 2270 culms/ha. This suggests that *Bambusa bambos* grows well at low and high altitude where there is optimal ecological requirement (Ohrnberger, 1999).

Generally, the stocking of Bamboo species in Tanzania is low compared to many studies in other countries. The low stocking of Bamboo is probably due to over-exploitation, grazing, shifting cultivation, fire and most importantly are mixed with other tree species (Chihongo *et. al.,* 2000). On the other hand, the mean basal area for bamboo species in Tanzania was 2.391 m^2/ha with the highest and lowest revealed in *Bambusa multiplex* (5.251 m^2/ha) and *Bambusa vulgaris* (0.532 m^2/ha). The variation of basal area for the different bamboo species might be determined by stand (culm) density and the diameter size of the species such that the higher the stocking and diameter size the higher the basal area and vice versa.

In terms of AGC and BGC, mean carbon storage for bamboo species in Tanzania was estimated to be 1.566 tC/ha. The reported mean carbon storage is within the range of reported carbon stock for bamboo in natural bamboo forest by other studies (Chihongo *et. al.*2000). Elsewhere, Houdanon *et. al.,* (2018) and Nath *et. al.* (2012) reported carbon stock range of 0.27 tC/ha to 14.85 tC/ha in Benin and 1.347 tC/ha to 13.851 tC/ha in Jharkland Asia, respectively which are comparable to carbon stocks reported in this study. The global Bamboo carbon assessment reported the carbon stock range of 16 to 128 tC/ha for AGC and 8 to 64 tC/ha for BGC (Yuen *et. al.,* 2017). This is higher than that found in this study. Apparent reason behind the smallest carbon stocks in Tanzania is that most bamboo species are mixed with other tree species unlike other countries where bamboo is grown in pure bamboo stands. Moreover, stand (culm) density, bamboo species types, climatic factors, and management practices, explains the differences as well (Nath *et. al.,* 2015).

The high density in the production forest land use is explained by presence of high level of species richness as compared by other land use type. Similarly, low density found in the grazing land, wildlife reserve, built up area and water bodies/swamp is associated with low species richness, meaning that only certain species are found in these land use types.

Land ownership imply different management regimes that may influence stocking. The high density in village land which also harbors high species richness may also imply preference for variety of species managed by communities.

Conclusions and recommendations

A study on the status of distribution, population structure and carbon storage of bamboo species in Tanzania was carried out by utilizing NFI data set. The study revealed 11 bamboo species of which three and eight species are indigenous and exotic, respectively. The most abundant species were *Arundinaria alpina* and *Oxytenanthera abyssinica* contributing about 55.9 % of the total abundance. All bamboo in the country are under two families of *Arundinarieae* and *Bambuseae.* The study revealed further that 85% of Bamboo species in Tanzania are found below 1500 m.a.s.l. The abundance, basal area, carbon and stocking of bamboo species is relatively low. Based on these findings, we recommend that, proper management intervention is required for the sustainability of bamboo resources in the country. Research should consider development of regional and site-specific models to determine volume and biomass of single bamboo tree in Tanzania. Due to lack of bamboo allometric biomass models in Tanzania, the models used in this study was borrowed from Kenya and Ethiopia, indicating the need to develop such models for Tanzanian bamboo species.

References

BPG 2012 . An updated tribal and subtribal classification of the bamboos (Poaceae: Bambusoideae). *The Journal of the American Bamboo Society* 24(1): 1 – 10.

Brown, S., Gillespie, A.J.R. and Lugo, A.E. 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. *Forest Science* 35: 881–902.

Bystriakova, N. and Kapos, V. 2006. Bamboo diversity: The need for a Red List review. [http://dx.doi.org/10.1080/14888386.2005.9712780] site visited on 23/10/2019.

Bystriakova, N., Kapos, V. and Lysenko, I. 2004. *Bamboo Biodiversity. Africa, Madagascar and the Americas*. United Nation Environmental Program-World Conservation Monitoring Centre. Cambridge. 89pp.

Chihongo, A. W., Kishimbo, S. I., Kachwele, M. D. and Ngaga, Y. M. 2000. *Bamboo Production-To-Consumption Systems in Tanzania.* Tanzania Forestry Research Institute, Tanzania. 35pp.

Djomo, A. N., Ibrahima, J.S, and G. Gravenhorst, G. .2010.; "Allometric equations for biomass estimations in Cameroon and pan moist tropical equations including biomass data from Africa". *Forest Ecology and Management*, vol. 260(10), pp.1873–1885.

Dutta, G. and Devi, A. .2013.. Plant diversity, population structure, and regeneration status in disturbed tropical forests in Assam, northeast India. *Journal of Forestry Research*

FAO 2007. *World Bamboo Resources: A Thematic Study Prepared in the Frame Work of Global Forest Resources Assessment 2005*. Food and Agriculture Organization of the United Nations, Rome, Italy. 73pp.

FAO 2010. *Global Forest Resources Assessment: Country Report United Republic of Tanzania*. Food and Agriculture Organization of the United Nations, Rome, Italy. 56pp.

Houdanon, R. D., Mensah, S., Gnanglè, C., Yorou, N. S. and Houinato, M..2018.. Ecosystem services and biomass stock from bamboo stands in central and southern Benin, West Africa. *Energy, Ecology and Environment* 3(3):185 – 194.

IPCC 2006.. *Guidelines for National Greenhouse Gas Inventories Agriculture, Forestry and other Land Use.* Institute for Global Environmental Strategies, Japan. 83pp.

IUCN 2013. *Hickelia africana*. The IUCN Red List of Threatened Species. [http://dx.doi.org/10.2305/IUCN.UK.20132.RLTS. T179344A1575697.en] site visited on 20/1/2020.

Judziewicz, E. J., Clark, L. G., Londono, X. and Stern, M. J. 1999. *American Bamboos*. Smithsonian Institution Press, Washington DC. 398pp.

Kigomo, B. N. 1988. Distribution, cultivation and research status of bamboo in Eastern Africa. *Ecology Series Monograph* 1: 1 – 19.

Kinyanjui, M., Latva. P., Bhuwneshwar. P. S., Gichu. A and Wanichwe. K. 2014 . An inventory of the above ground biomass in the Mau forest ecosystem. *Open Journal of Ecology* 4: 619 - 627.

Liese, W. and Köhl, M. Eds 2015 . *Bamboo: The Plant and Its Uses*. Springer Publishers, Swaziland. 356pp.

Lovett, J. C. 1994 . Notes on moist forest bamboos and bambusoid grasses in Eastern Tanzania. *East Africa National History Society Bulletin* 24(1): 2 – 5.

MacDicken, K.G. 1997. *A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects.* Report No. 1611. International Institute for Agricultural Development, Arlington, USA. 87pp.

Magurran, A. E. 1988 . *Ecological Diversity and Its Measurement*. Great Britain University Press, Cambridge. 45pp.

Mbuya, L. P., Msanga, H. P., Ruffo, C. K., Birnie, A. and Tengnäs, B. 1994 . *Useful Trees and Shrubs for Tanzania Identification, Propagation and Management for Agricultural and Pastoral Communities*. Regional Soil Conservation Unit English Press., Nairobi, Kenya. 542pp.

Mishra, G., Giri, K., Panday, S., Kumar, R. and Bisht, N. S. 2014 . Bamboo: potential resource for eco-restoration of degraded lands. *Journal of Biology and Earth Sciences* 4(2): 130 – 136.

MNRT 2000. *The Status of Non-Timber Forest Products in Tanzania. Forest Division.* Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania.12pp.

MNRT 2015 . *National Forest Resources Monitoring and Assessment Main Results. Tanzania Forest Services*. Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania. 106pp.

Moges, Y., Eshete, Z. and Sisay, N. 2010 . *Ethiopian Forest Resources: Current Status and Future Management Options in View of Access to Carbon Finances, Ethiopian Climate Research and Networking*. United Nations Development Programme, Addis Ababa, Ethiopia. 82pp.

Nath, S., Tamta, B. P., Chandrashekhar, B. S., Panwar, V. P., Das, P. K. and Krishnamurty, R. (2012). Bamboo resources of Jharkhand. *Indian forester* 138(5): 422 – 433.

Ohrnberger, D. 1999 . *The Bamboos of the World: Annotated Nomenclature and Literature of the Species and the Higher and Lower Taxa*. Elsevier Publishers, Amsterdam. 585pp.

Oyen, L.P.A. (2011). *Hickelia Africana* A. Camus plant resources of tropical Africa. [http://apps.kew.org/wcsp/] site visited on 23/01/2020.

Philip, M. S. 2004. *Tree and Forest Measurement*. Springer-Verlag Berlin Heidelberg, New York. 170pp.

Seethalakshmi, K. K. and Kumar, M. S. M. 1998 . *Bamboos of India: A Compendium*. Kerala Forest Research Institute, New Delhi, India. 342pp.

Shimada, A. and Wilson, M. W. 1985 . Biological determinants of species diversity. *Journal of Biogeography* 12:1 – 20.

Son, N. H. 2011. Data cleaning and Data preprocessing. [http://www.mimuw.edu.pl/~son/datamining/DM/4-preprocess.pdf] site visited on 8/12/2019.

Song, X., Zhou, G., Jiang, H., Yu, S., Fu, J., Li, W., Wang, W., Ma, Z. and Peng, C. 2011. Carbon sequestration by Chinese bamboo forests and their ecological benefits: assessment of potential, problems, and future challenges. *Environmental Reviews* 19: 418 – 428.

Tomppo, E., Malimbwi, R., Katila, M., Mäkisara, K., Henttonen, H. M., Chamuya, N., Zahabu, E. and Otieno, J. 2014 . A sampling design for a large area forest inventory: Case Tanzania. *Canadian Journal of Forest Research* 44:931 – 948.

Tomppo, E.; Katila, M.; Makisara, K.; Malimbwi, R.; Chamuya, N.; Otieno, J.; Dalsgaard, S.; Leppanen, M. A 2010. Report to the Food and Agriculture Organization of the United Nations (FAO) in Support of Sampling Study for National Forestry Resources Monitoring and Assessment (NAFORMA) in Tanzania. Available online at https://www.google.com/search?source=hp&ei=ENG1W77nGYq-a8u2qfgH&q (accessed on 13 December 2019)

Vashum, K.T and Jayakumar S. 2012; Methods to estimate aboveground biomass and carbon stock in natural forests - A Review. *Journal of ecosystem and Ecography* 2(4) 116pp.

Vorontsova, M. S., Clark, L. G., Dransfield, J. and Barker, J. 2016. *World Checklist of Bamboo.* Technical Report No. 37. International Network for Bamboo, Rattan. 466pp.

Walker, S. M., Murray, L. and Tepe, T. 2016. Allometric equation evaluation guidance document. [https://www.winrock.org/document/allometric-equation-evaluation-guidance-document/] Site visited on 8/11/2019.

Whittaker, R. H. 1972. Evolution and the measurement of species diversity. *Taxon* 21: 213 – 251.

Yuen, J. Q., Fung, T. and Ziegler, A. D. 2017. Carbon stocks in bamboo ecosystems worldwide: Estimates and uncertainties. *Forest Ecology and Management* 393: 113 – 138.