



Original Article

Analysis of Floristic Diversity and Quantification of Diameter Class Aboveground Biomass (AGB) and Carbon Stocks of Afromontane Vegetation of Nkoanenkole Forest Reserve (NCFR) in Northern Tanzania

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Aboveground Biomass,
Carbon Stocks,
Nkoanenkole Catchment,
Forest Reserve.

Nkoanenkole Forest Reserve (NCFR) is such a potential area in floristic diversity within a relatively small area of 370.2 ha. The study was conducted in 2018 to analyze the floristic diversity and quantify the tree species aboveground biomass and carbon stocks of Nkoanenkole Catchment Forest Reserve (NCFR) in Arumeru District, Arusha-Tanzania. Systematic random sampling was applied, whereby a total of 24 plots with a 15 m radius (706.5 m²) were set at an inter plot and transect distance of 350 m. The plant species were identified by their botanical names, determined for abundance, and trees with ≥ 5 cm DBH were measured. Shannon Wiever (H'), and Simpson indices were applied to calculate the index of diversity. Also, density and relative density were calculated. The AGB and AGC mg ha⁻¹ were calculated using allometric models. 147 plant species were identified from the 24 sample plots, of which 54 were trees, 31 shrubs and lianas, 48 herbs, 3 sedges, 6 grass species, and 6 belonged to the ferns. The calculate H' was 3.3316 for trees with an index of dominance of 0.053, and 2.449 for shrubs and lianas, sedges, herbs, and ferns with an index of dominance of 0.00.3135. The families of Euphorbiaceae, Rubiaceae, Fabaceae, and Asteraceae were determined to be the most dominant in terms of the number species. The identified tree seedlings were 14 with an abundance of 136, the density of 16.513 \pm 0.590, and a relative density of 20.14 \pm 0.73. *Bersama abyssinica* and *Psychotria riparia* were the most dominant tree seedlings. The DBH-class of 15 \pm 5 had the highest AGB (kg) and AGC mg ha⁻¹, followed by 25 \pm 15, 55 \pm 45, 65 \pm 55, and the rest. NCFR is latent for its biodiversity, hence recommending further study on biological diversity, the possibility for upgrading the NCFR to the nature reserve, encourage beekeeping as potential

pollinators, discourage illegal human activities through education and regular patrols.

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INTRODUCTION

It has been stated that globally, 52% of the total forests are in tropical regions and they are known to be the most important areas in terms of biodiversity. The diversity is an indicator that allows appreciating the links between the richness and the abundance of individual trees (Ifo et al., 2016). Fumilayo (2014) and Ifo et al. (2016) add that tropical forests have been a subject for several studies aimed at providing a better understanding of the role they play in sustainable development, climate change, and floristic biodiversity. Tropical forests provide many goods and ecosystem services such as prevention of soil erosion and preservation of habitats for plants and animals. Tanzania is very rich in natural resources existing in the terrestrial and aquatic ecosystem, including flora and fauna. Tanzania has about 33.5 million hectares of forests and woodlands, making up about 36% of its total land area (MNRT, 1998). Out of this area, about 13 million hectares have been gazetted as forest reserves; and about 1.6 million hectares are under the water catchment management (MNRT, 1998; URT, 2009).

Catchment forests in Tanzania are mostly tropical moist forests found mainly in mountainous areas (URT, 2002). The water catchment forest is an area surrounding watercourse and providing it with water (FAO, 2011). Tanzania's catchment forests are increasingly becoming important resources in supporting the livelihood of the majority of rural and urban populations as well as conserving potential ecological areas ensuring a sustained supply of water (URT, 2002). The NCFR is a source of water, hence has water catchment value (Kashenge, 1986). The water is piped and distributed to the Usa River Township for domestic use and irrigation farming (Kayombo et al., 2017). Forests have the ecological functions of encouraging rainfall, water catchment, stabilizing water flows, reducing erosion, landslides, and floods in areas of steep topography and high precipitation. They are areas of high biodiversity (Forbes & Broadhead, 2011). The forests have an important function of supporting large populations downstream with water for irrigation, hydroelectricity and industrial use, but also for livestock among other domestic uses. Forest reserves in Tanzania cover about 36.8% of the country. However, illegal logging and clearing of

forest and woodland for farming and charcoal making are accelerating with losses put at over 91,000 hectares per annum. 15% of Tanzania's forest cover was lost between 1990-2005 (URT, 2002).

Nkoanenkole Catchment Forest Reserve Resources (NCFR) Floristic Diversity Potential

Nkoanenkole Catchment Forest Reserve (NCFR) has an area of 370.2 ha (3,702,000 m²). It is situated at the foot of Mount Meru and accommodates relatively high biological diversity; its sustainability remains dependent the human conservation efforts. NCFR has a huge potential for water catchment and habitat for wild flora and fauna, as well as maintaining the natural scenery. The sustainability of forest resources is well cared when the contained organisms are systematically being determined for their existence, diversity, abundance and forms (herbs, sedges, shrubs, lianas, trees), and stand density. Stand density is a management tool that helps forest managers to more effectively manage the forests and forest resource determination (Kara, 2018). NCFR plays a role as a carbon sink, protection of soil erosion, windbreak, and regulation of temperature and rainfall, a provision that calls for its sustainability rather than consumption of the resource.

Aboveground Biomass ad Carbon Stocks

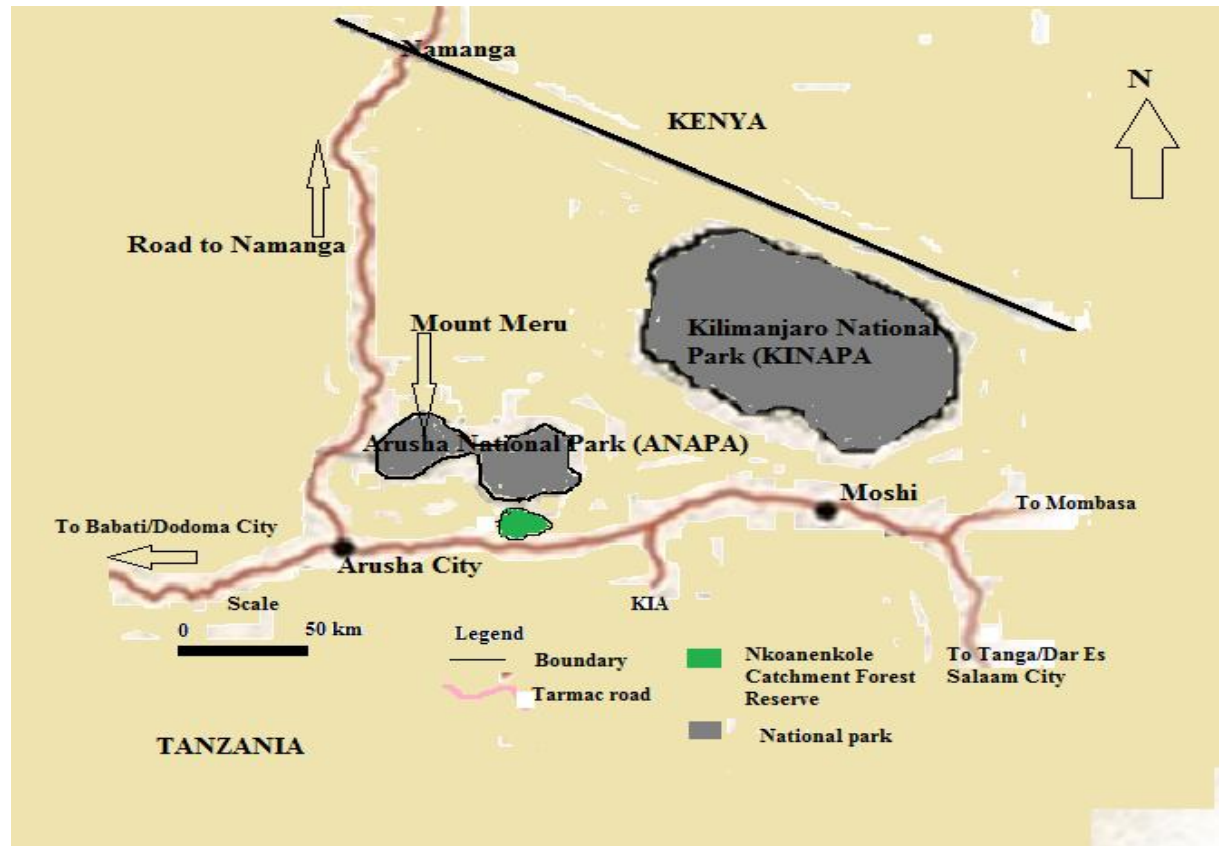
Forest carbon stock is a time-integrated expression of numerous processes ranging from plant growth and mortality to natural disturbance and human land use (Asner et al., 2018). NCFR is among the

protected forest with inadequate information on biological diversity, and composition, and aboveground biomass and carbon stocks (AGCmg ha⁻¹) just like in many other countries in the world. National Research Council (2008) stated that the global importance of tropical forests reflects both their enormous biodiversity, which includes a high proportion of endemic species, and their importance to planet earth experiencing the greenhouse effect, as fast sinks for carbon, yet it is remarkable how little we know about their diversity. This study intended to analyse the existing floristic diversity of Nkoanenkole Catchment Forest Reserve (NCFR).

MATERIAL AND METHODS

Description of Nkoanenkole Catchment Forest Reserve (NCFR)

The NCFR is located between Latitude of 3° 19' and 3° 20' South of Equator and between Longitude of 36° 50' and 36° 52' East of Greenwich Meridian (Kayombo et al., 2017). The NCFR is about 3.5 km North of Usa River Township and 28 km North-East of Arusha City. The altitude ranges from 1300 - 1800 m above sea level (Kayombo et al., 2017). NCFR lies on the southern foot of Mount Meru in the Arusha National Park (*Figure 1*). It borders the Meru-Usa Plantation to the north, Nkoanenkole village to the north-west, west and to the south. NCFR border four villages which are Ngongongare to the east, Nkoanenkole to the south, Nkure to the south-west and west, and Kalinga to the west. NCFR covers an area of 370.2 ha (3,702,000m²).

Figure 1: Location of Nkoanenkole Catchment Forest Reserve (NCFR)

NCFR is underground water sub-Afromontane forest dominated by *Celtis africana*, *Vepris simplicifolia*, *Tabernaemontana ventricosa*, *Rauvolfia caffra*, *Rothmannia urceliformis*, *Trilepesium madagascariensis*, *Diospyros usambarensis* and *Albizia schimperiana* to list a few (Kayombo et al., 2017). Apart from being a somewhat homogenous vegetation type, the following vegetation types were described during the survey: moist forest, dry forest, and bushland patches. The moist forest area composed of high canopy coverage and the dominant trees were; *Tabernaemontana ventricose*, *Croton sylvaticus*, *Ekebergia capensis*, *Psychotria riparia*, *Casearia battiscombei*, and *Trichilia emetica*. The dry forest area was occupied by *Cordia africana*, *Euclea divinorum*, *Celtis Africana*, *Olea capensis* and *Diospyros abyssinica*. The bushland was dominated by *Vernonia myriantha* mixed with *Caesalpinia decapetala* in some parts of NCFR, while some parts were completely dominated by the alien plant, *Caesalpinia decapetala*, and rarely with *Lantana camara*.

The NCFR experiences the oceanic rainfall with continental temperatures. Rainfall on the southern slopes of Mount Meru is up to 2000 mm per year, while the northern slopes which are meant to be Leeward side receive rainfall between 500-600 mm per year (Kashenge, 1986). The mean annual temperature is between 17 and 20 °C at lower altitudes. The soils are andosols on young volcanic stone (basalt lava) rich in nutrients and alkaline (soda); at higher altitudes, the soil is leached, forming acidic lithosols (Kashenge, 1986).

Data Collection and Analysis

A total of 24, 15 m x 15 m (225 m²) plots as calculated from $n = \frac{CV^2 t^2}{E^2}$ were set at an interplot and transect distance of 350 m. Since the vegetation of the study area was almost homogenous, systematic random sampling technique based on set transects and plots was performed, whereby the first plot was set randomly between 50 - 100 m from the forest edge, trailed systematically. The floristic diversity investigation was done as per methods

used by Frontier-Tanzania (2004). Plot location was recorded using GPS for future monitoring. The collected data on plant species were on botanical names, their species abundance. All trees with a diameter breast height, at 1.3 m from ground ≥ 5 cm from both the canopy and sub-canopy layers, were recorded, counted and identified. The frequency of encounter of each species and its abundance was also counted and recorded. Regeneration plot within 2 m radius was laid out at the centre of 15 m radius plot to record, count and identified tree sapling, seedlings and non-woody plant species including grasses, herbs, sedges, ferns and shrubs. An observed plant species that were not recorded before in the plots were recorded. Plant species specimens were collected for further identification at the National Herbarium of Tanzania (NHT).

Shannon Wiener and Simpson indices were applied to calculate the diversity indices, while aboveground biomass and volume models were calculated using the biomass and volume models.

Computation of vegetation indices

i. Diversity Indices

Shannon Index of Diversity (H') and Simpson Index (ID):

$$H' = -\sum p_i \ln p_i \text{ (Kent, 2012) } \dots\dots\dots [1]$$

$$ID = \frac{1}{\sum p_i^2} \text{ (Kent, 2012) } \dots\dots\dots [2]$$

$$J = \frac{H'}{S} \dots\dots\dots [3]$$

Family dominance % (FD%)

$$D\% = \frac{n \sum n_{GE}}{\sum N_{GE}} \times 100\% \dots\dots\dots [4]$$

Quantification of biomass and carbon stocks

The allometric equations developed by Masota *et al.* (2016) for the montane forest with DBH and height as input parameters were used to estimate the

individual tree aboveground biomass. Then, the biomass of each individual tree was converted into carbon in tons per hectare by multiplying biomass by 0.49 (percentage forest default value of aboveground carbon dry mass) (IPCC, 2006).

ii. Allometric Models

Above Ground Biomass (AGB):

$$AGB = 0.9635 \times dbh^{1.9440} \text{ (Masota } et al., 2016) \dots\dots\dots [5]$$

Tree Volume Model:

$$Vm^3 = e^{-7.41201} + 2.1901527 \times \ln(dbh) \text{ (Masota } et al., 2016) \dots\dots\dots [6]$$

RESULTS AND DISCUSSION

Floristic Diversity of Nkoanenkole Catchment Forest Reserve (NCFR)

It has been stated that the concept of plant species diversity includes two components: species richness and evenness. Species richness is the number of species per unit area while evenness is the abundance distribution of species in a community; also, there is a positive correlation between these indices; however, high species richness is not necessarily accompanied by high-degree evenness (Vasilevich, 2009). The study identified a total of 147 plant species from the 24 sample plots. Those plant species belonged to 56 families and 127 genera (Table 1). Out of the 147 plant species, 54 belonged to tree forms, while 93 were shrub, liana, sedge, herb, grass, and ferns (Table 2). The plant species diversity was facilitated by suitable habitat and reliable amount of rainfall supporting the growth of a variety of plants. Stevenson *et al.* (2012) supported that the distribution of plant sites is associated with ecological variables, among them being rainfall and temperature.

Table 1: Plant species families, genera, and species of Nkoanenkole Catchment Forest Reserve

Family Name	No.	Botanical name
Acanthaceae	1	<i>Barleria cristata</i>
	2	<i>Hypoestes aristata</i>
	3	<i>Hypoestes forskalii</i>

Family Name	No.	Botanical name
	4	<i>Justicia flava</i>
	5	<i>Microglossa pyrifolia</i>
Adiantaceae	6	<i>Pellaea viridis</i>
Alangiaceae	7	<i>Alangium chinense</i>
Amaranthaceae	8	<i>Achyranthes aspera</i>
	9	<i>Cyathula cylindrica</i>
	10	<i>Cyathula uncinulata</i>
Apocynaceae	11	<i>Tabernaemontana ventricosa</i>
	12	<i>Mondia whitei</i>
	13	<i>Rauvolfia caffra</i>
	14	<i>Pentarrhina abyssinicum</i>
	15	<i>Secamone punctulata</i>
Araliaceae	16	<i>Cussonia holstii</i>
Asparagaceae	17	<i>Asparagus setaceus</i>
Aspleniaceae	18	<i>Asplenium strangeanum</i>
	19	<i>Asplenium erectum</i>
Asteraceae	20	<i>Ageratum conyzoides</i>
	21	<i>Bidens pilosa</i>
	22	<i>Conyza bonariensis</i>
	23	<i>Montanoa hibiscifolia</i>
	24	<i>Neonotonia wightii</i>
	25	<i>Senecio syringifolia</i>
	26	<i>Tithonia diversifolia</i>
	27	<i>Vernonia sp</i>
	28	<i>Vernonia galamensis</i>
Boraginaceae	29	<i>Cordia africana</i>
	30	<i>Ehretia cymosa</i>
Capparaceae	31	<i>Ritchiea albersii</i>
	32	<i>Capparis tomentosa</i>
Caricaceae	33	<i>Carica papaya</i>
Celasteraceae	34	<i>Salacia madagascariensis</i>
Commelinaceae	35	<i>Commelina benghalensis</i>
Convolvulaceae	36	<i>Cuscuta kilimanjari</i>
	37	<i>Ipomoea wightii</i>
Cucurbitaceae	38	<i>Momordica foetida</i>
	39	<i>Zehneria scabra</i>
Cyperaceae	40	<i>Carex chlorosaccus</i>
	41	<i>Scleria muhlenbergiana</i>
	42	<i>Scleria foliosa</i>
Dennstaedtiaceae	43	<i>Blotiella glabra</i>
Dracaenaceae	44	<i>Dracaena afromontana</i>
Ebenaceae	45	<i>Diospyros abyssinica</i>
	46	<i>Euclea divinorum</i>
Euphorbiaceae	47	<i>Bridelia micrantha</i>
	48	<i>Croton macrostachyus</i>
	49	<i>Croton sylvaticus</i>
	50	<i>Neobotonia macrocalyx</i>
	51	<i>Ricinus communis</i>
	52	<i>Acalypha ornata</i>

Family Name	No.	Botanical name
	53	<i>Acalypha paniculata</i>
	54	<i>Acalypha racemosa</i>
	55	<i>Acalypha volkensii</i>
	56	<i>Clutia abyssinica</i>
	57	<i>Erythrococca fischeri</i>
	58	<i>Phyllanthus ovalifolius</i>
	59	<i>Tragia brevipes</i>
Fabaceae	60	<i>Albizia gummifera</i>
	61	<i>Amphicarpaea africana</i>
	62	<i>Caesalpinia decapetala</i>
	63	<i>Crotalaria axillaris</i>
	64	<i>Dalbergia lactea</i>
	65	<i>Desmodium repandum</i>
	66	<i>Pterolobium stellatum</i>
	67	<i>Senna semptilionalis</i>
Flacourtiaceae	68	<i>Casearia battiscombei</i>
	69	<i>Dovyalis abyssinica</i>
	70	<i>Oncoba spinosa</i>
Lamiaceae	71	<i>Hoslundia opposita</i>
	72	<i>Leuca densiflora</i>
	73	<i>Ocimum gratissimum</i>
	74	<i>Clerodendrum johnstonii</i>
	75	<i>Rothea myricoides</i>
Loganiaceae	76	<i>Strychnos henningsii</i>
Malvaceae	77	<i>Abutilon longicuspe</i>
	78	<i>Pavonia urens</i>
	79	<i>Sida acuta</i>
Meliaceae	80	<i>Ekebergia capensis</i>
	81	<i>Trichilia emetica</i>
	82	<i>Turraea holstii</i>
	83	<i>Turraea robusta</i>
Meliantaceae	84	<i>Bersama abyssinica</i>
Menispermaceae	85	<i>Stephania abyssinica</i>
Moraceae	86	<i>Ficus exasperata</i>
	87	<i>Ficus ingens</i>
	88	<i>Ficus lutea</i>
	89	<i>Ficus sur</i>
	90	<i>Ficus thonningii</i>
	91	<i>Trilepesium madagascariensis</i>
Myrsinaceae	92	<i>Embelia schimperi</i>
Myrtaceae	93	<i>Syzygium guineense</i>
Oleaceae	94	<i>Olea capensis</i>
Opiliaceae	95	<i>Opilia amentacea</i>
Oxalidaceae	96	<i>Oxalis corniculata</i>
	97	<i>Oxalis latifolia</i>
Phytolaccaceae	98	<i>Phytolacca dodecandra</i>
Piperaceae	99	<i>Peperomia retusa</i>
Poaceae	100	<i>Cynodon dactylon</i>
	101	<i>Oplismenus compositus</i>

Family Name	No.	Botanical name
	102	<i>Panicum platycladum</i>
	103	<i>Setaria giganteus</i>
Polypodiaceae	104	<i>Drynaria rigidula</i>
	105	<i>Pleopeltis excavata</i>
Pteridaceae	106	<i>Pteris catoptera</i>
Ranunculaceae	107	<i>Clematis simensis</i>
Rhamnaceae	108	<i>Gouania longispicata</i>
	109	<i>Helinus mystacinus</i>
	110	<i>Scutia myrtina</i>
Rosaceae	111	<i>Abrus precatorius</i>
	112	<i>Fragaria vesca</i>
	113	<i>Rubus pinnatus</i>
Rubiaceae	114	<i>Coffea arabica</i>
	115	<i>Lasianthus kilimandscharicus</i>
	116	<i>Oxyanthus speciosus</i>
	117	<i>Psychotria riparia</i>
	118	<i>Rothmannia urcelliformis</i>
	119	<i>Vangueria madagascariensis</i>
	120	<i>Canthium uhligii</i>
	121	<i>Pavetta</i> sp.
	122	<i>Rubia cordifolia</i>
Rutaceae	123	<i>Citrus lemon</i>
	124	<i>Clausena anisata</i>
	125	<i>Fagaropsis angolensis</i>
	126	<i>Vepris simplicifolia</i>
	127	<i>Toddalia asiatica</i>
Sapindaceae	128	<i>Allophyllus abyssinica</i>
	129	<i>Allophyllus africanus</i>
	130	<i>Blighia unijugata</i>
Sapotaceae	131	Sapotaceae
Simaroubaceae	132	<i>Brucea antidycenterica</i>
Smilacaceae	133	<i>Smilax kraussiana</i>
Solanaceae	134	<i>Solanum aculeatissimum</i>
	135	<i>Solanum anguivi</i>
	136	<i>Solanum terminale</i>
Sterculiaceae	137	<i>Dombeya kirkii</i>
Thymeliaceae	138	<i>Peddiea fischeri</i>
Tiliaceae	139	<i>Grewia similis</i>
	140	<i>Triumfetta rhomboidea</i>
Ulmaceae	141	<i>Celtis africana</i>
	142	<i>Chaetacme aristata</i>
	143	<i>Trema orientalis</i>
Urticaceae	144	<i>Girardinia diversifolia</i>
Vitaceae	145	<i>Ampelocissus africana</i>
	146	<i>Cyphostemma adenocaula</i>

According to their growth forms, 54 were trees, 31 included shrubs and lianas, 48 were herbs, 3 were sedges, 6 were grasses, and 6 belonged to the ferns

(Table 2). The computations revealed high plant species diversity as a rule that the higher the H' the higher the diversity and the vice versa is true, while

the lower the ID, the higher the diversity and the vice versa is true in the scale of 0 to 1. From the survey findings it has been noted that due to presence of high diversity of vegetation categories classified from the study area, there is also a high diversity of species as well as life forms (Table 1). The survey identified a total of 147 plant species. The largest species composition was from trees (36.73%) trailed by herbs (31.97%), shrubs including lianas (21.09%), grasses and sedges (4.08% each), and sedges were ranked the least (2.04%). (Table 2).

Table 2: Total number of plant species per growth form category

Growth form	Total species	%
Trees	54	36.73
Shrubs & lianas	31	21.09
Sedges	3	2.04
Grasses	6	4.08

Table 3: Plant species density, Shannon Wiever (H'), and Simpson indices, evenness, and reciprocal

Growth category	Density	H'	ID	J	R
Trees	306.086	3.33	0.05	0.84	18.87
Sr,Hb,Gr, Sg, Fn	1459.71	2.45	0.31	0.54	3.19

Key: J=evenness; R=reciprocal; Sr = shrub; Hb=herb; Gr=grass; Sg=sedge; Fn=fern

The most dominant trees were *T. ventricosa*, *E. divinorum*, *D. abyssinica*, *C. anisata*, *B. unijugata*, *B. abyssinica*, *C. africana*, *C. sylcaticus* and *C. africana*. While *A. aspera*, *O. compositus*, *T. brevipes*, *Setaria sp.*, *T. diversifolia* and *S. foliosa* were among dominant plants form the other growth forms (shrubs, herbs, grasses and sedges) (Table 2). Ifo et al. (2016) conducted a study in the tropical forests of Congo revealed that those trees species with the largest number of stems were the most dominant.

Growth form	Total species	%
Ferns	6	4.08
Herbs	47	31.97
Total	147	100

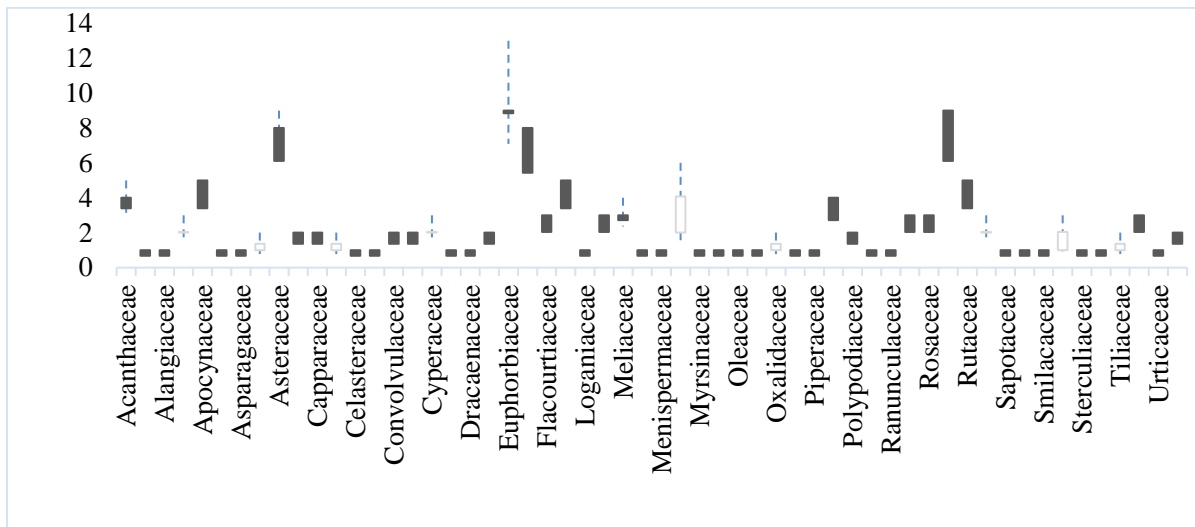
Floristic Species Density (H') and Dominance

The identified tree species had a density of 306.086 while the other forms got a density of 1459.071, with the H' of 3.3316 for trees and 2.44911 for other growth forms (Table 3). Both trees and other growth forms were not evenly distributed (Table 3) with a J of 0.84 and reciprocal (R) of 18.87 for trees and 0.54 (J) and 3.19 (R) for shrubs, herbs, sedges, grasses and ferns. The unevenness results meant there was unequal abundance of the identified and counted plant species from the sample plots. Verberk (2011) reported that the variation in the number of stems of the plant species lead to the unevenness of plant species distribution as it depends on the number of stems of the plants.

Plant families of Nkoanennkole Catchment Forest Reserve (NCFR)

The most dominant families got the highest number of genera and species of all others. The most dominant families were; Euphorbiaceae with 7.087% for genera and 8.844% for species; Rubiaceae (7.08% for genera and 6.122% for species); Fabaceae (6.299% for genera and 5.442 for species); Asteraceae with 6.299% for genera and 6.122% for species (Figure 2).

Figure 2: Family species dominance based on the number of genera and species percentages



Tree Species Seedlings Density and Relative Density

The sustainability of the vegetation cover is grounded on the successive stages of plant growth from seed bank germination, seedling, sapling, poles and finally a mature tree. The survey identified 14 tree species seedlings (Table 4). This indicated the NCFR sustainability, as the mature

trees will die, they are replaced by the poles, while poles will be replaced by the saplings and the saplings will be replaced by the seedlings. Of all tree seedlings, *P. riparia* was the highest in terms of density per hectare (16.51), *B. abyssinica* (11.795), *C. africana* (10.026), *V. simplicifolia* (9.436), *D. abyssinica* (7.667), *S. guineense* and *T. ventricosa* (5.898), while the rest got a density of less than 5 (Table 4).

Table 4: Tree species seedlings density and relative density

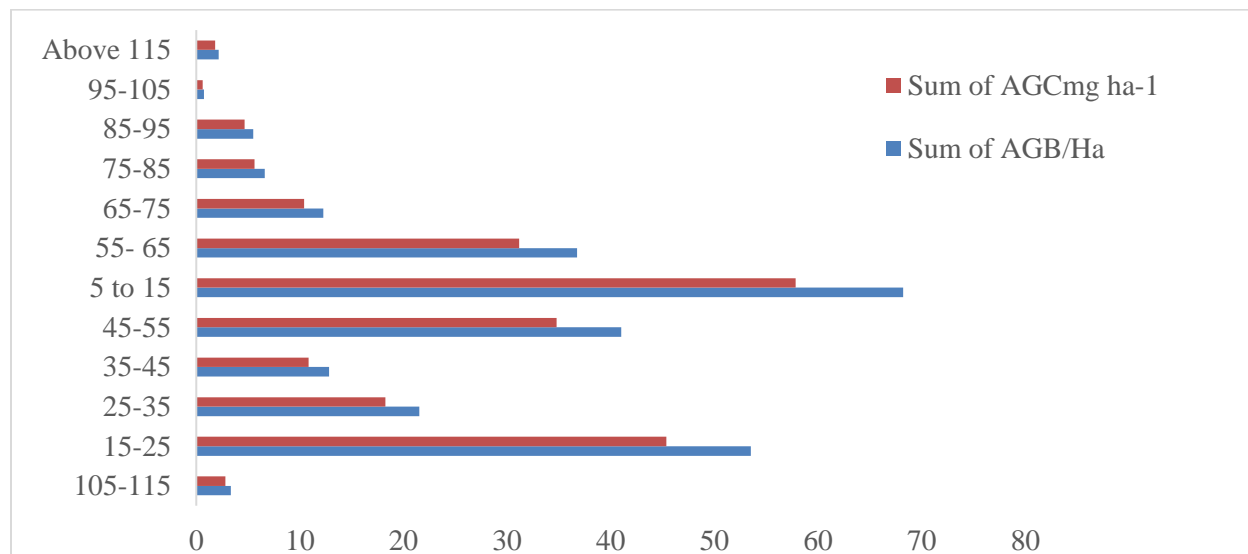
Scientific Name	Abundance	Density	Relative Density
<i>Allophyllus africanus</i>	5	2.949	3.60
<i>Bersama abyssinica</i>	20	11.795	14.39
<i>Blighia unijugata</i>	4	2.359	2.88
<i>Celtis africana</i>	17	10.026	12.23
<i>Coffea arabica</i>	2	1.180	1.44
<i>Diospyros abyssinica</i>	13	7.667	9.35
<i>Peddiea fischeri</i>	3	1.769	2.16
<i>Psychotria riparia</i>	28	16.513	20.14
<i>Ritchiea albersii</i>	1	0.590	0.72
<i>Syzygium guineense</i>	10	5.898	7.19
<i>Tabernaemontana ventricosa</i>	10	5.898	7.19
<i>Trichilia emetica</i>	8	4.718	5.76
<i>Turraea robusta</i>	2	1.180	1.44
<i>Vepris simplicifolia</i>	16	9.436	11.51
Total	139	81.98	100

Tree Species Aboveground Biomass and Carbon Stocks per Diameter Class

The study revealed that those classes with large basal area per hectare also had larger biomass per hectare. The AGB ranged from 68.22 ± 3.32 (Figure 3), with AGC mg ha⁻¹ of 57.835 ± 2.815 (Figure 3). The DBH-class of 15 ± 5 was revealed to have the highest AGBkg/Ha and AGC mg ha⁻¹, trailed by DBH-class 25 ± 15 , 55 ± 45 , 65 ± 55 , 35 ± 25 and others (Figure 3). The highest AGB and AGC for the DBH-class 15 ± 5 was facilitated by the number of stems measured from the sample plots (Figure 3), while the least, from DBH-class

>115 and 115 ± 105 (Figure 3), was due to the least number of stems measured from the sample plots. This entailed few old trees than the younger trees that were going to take off in the future, and hence forest future sustainability. The larger the diameter, the larger the AGB and AGC, and the vice versa is true. Dean (2004); Balderas Torres and Lovett (2013) highlighted that there is a linear relationship between the standing tree diameter or basal area and above-ground biomass. Also, Shirima et al. (2014) highlighted that there is a relationship between plant species richness, evenness and aboveground biomass and carbon.

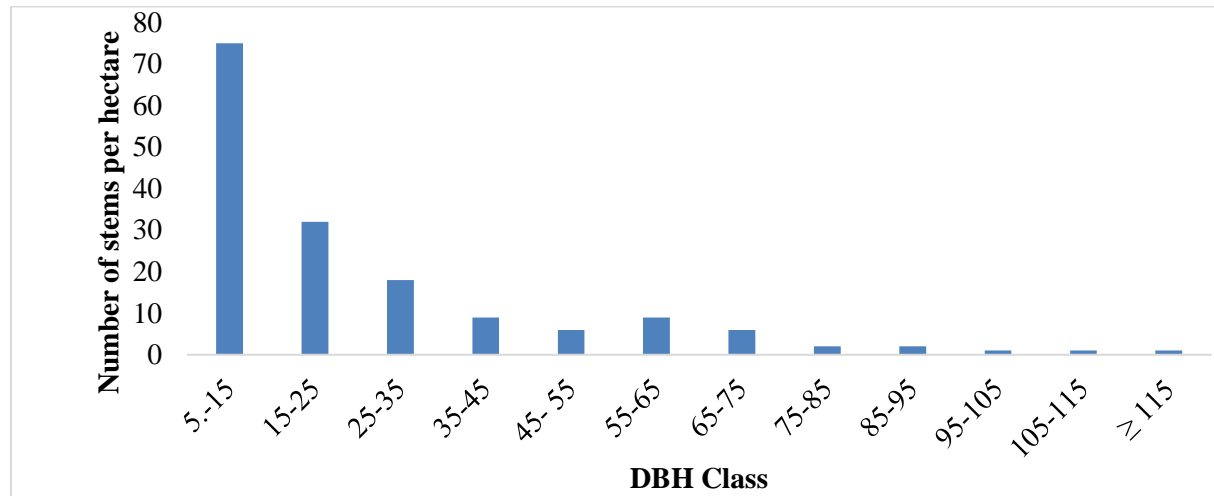
Figure 3: Aboveground Biomass (AGB) for NCFR



Forest Stocking with Respect to Diameter Classes

The estimation of the number of trees per acre or hectare is one way of determining the tree stocks, while others are basal area as calculated from measured DBH, and volume (Martin, 1986). The study found that there was a decrease in the number of stems from low-class diameter to high-class diameter, an implication that there was a sort of harvesting of trees with a larger diameter. On the other hand, this is a case in a natural forest where

there tend to be active regeneration and a mixture of trees of various age classes. Initially, some years back there had been severe harvesting of larger trees for timber, and even recently, there had been rare poaching for the same too. The large diameter tree species found in NCFR entail the serious protection by TFS. The DBH class of $75 - \geq 115$ cm showed the lowest stocking, and this can be assumed being resulted from overexploitation, as this class could suite the human consumption interest for timber, and other needs requiring large boles.

Figure 4: Number of stems per hectare of standing tree diameter by classes at NCFR

CONCLUSION

Nkoanenkole Catchment Forest Reserve has been revealed to contain high floristic diversity-supporting the water catchment areas for the benefit of bordering community, carbon sinks, rainfall and temperature regulation, windbreak and as wildlife habit for wildlife. Further studies on biological species are needed, upgrading the nature reserve, forest conservation education and awareness creation to the local community by the Tanzania Forest Service (TFS) is needed.

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