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COVER

Mature *Oxystigma msoo* in Rau Forest Reserve, Kilimanjaro, Tanzania

The tree species is among the red listed vulnerable and threatened species to extinction. The tree species may become extinct if urgent conservation measures are not taken.

TAFORI Newsletter is published twice a year by Tanzania Forestry Research Institute. Contributions to the Newsletter are invited from members of the public having relevant information about forestry research and development in Tanzania. The views expressed in the TAFORI Newsletter are those of the authors and do not necessarily represent the views of the Editorial Board or any other establishment associated with TAFORI.

THE OVERVIEW OF DIRECTORATE OF FOREST UTILISATION RESEARCH

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Abstract
Directorate of Forest Utilisation Research (DFUR) has six departments namely wood machining, wood chemistry, wood energy, and wood structure, socio – economic and marketing. This overview presents past and present researches conducted by the directorate since 1948. About 250 timber tree species out of 700 had been studied for their utilisation properties. Most of the researches done are on utilisation properties of timbers, medicinal plants, natural durability of indigenous and exotic trees grown in Tanzania both marine and terrestrial and testing wood energy from various tree species. The findings are categorized based on the major research areas.

Keywords: *Forest products, utilisation, forest operation, wood energy, research.*

Introduction
Directorate of Forest Utilisation Research (DFUR) is one of three directorates in Tanzania Forestry Research Institute (TAFORI). The DFUR vision is increased communities' and other stakeholders' involvement in forest products development and marketing to enhance poverty reduction, improved health, food security, increased income and sustainable management and conservation of forest resources in Tanzania. The mission is to carry out forest utilization research and transfer technologies that will increase the number of benefits obtained from both indigenous and exotic tree species in response to existing and or emerging forest utilization trends. These are geared to make TAFORI a centre of excellence in forestry research. The aim of this overview was to share some researches that had been done for the past over 60 years. Research activities carried out by the DFUR follow the National Forestry Research Master Plan (NAFORM) (URT, 1992; 1999; 2011) and TAFORI CSP (TAFORI, 2012). Researches in this directorate basically focused on forest utilisation in Tanzania specifically on forest products and operations. Forest products include timber and non timber products. Research on timber products focused on utilisation properties (Bryce *et al*., 1967), wood energy (Kimario *et al*., 1980; TAFORI, 2012; TAFORI, 2010), wood structure, timber engineering (wood machining) and wood chemistry (Bryce, 1967; Malde, 1970; Chihongo, 1999). Research on non timber forest products focused on its availability, utilisation, processing, packaging, storing and marketing (Mbwambo *et al*., 2007; Kimario *et al*., 1985). Forest operations researches include harvesting techniques (Bakari *et al*., 2006); disturbances in the forest like the cause of death of camphor in Chome Forest Reserve and *Grevillea robusta* in Meru Forest Plantation Arusha (TAFORI, 2010; 2011); causes of massive death of bamboo and assessing vegetation recovery in Uzungwa Scarp Forest Reserve Kilolo (TAFORI, 2010, 2011 and 2012), Other researches based on forest products development and marketing (Kimario *et al*., 1979; Mbwambo *et al*, 2008; Kapinga, *et al* 2009; TAFORI, 2011; 2012).

Methods
The information was obtained through reading various literature published by Utilisation section, Forest division, Technical notes in Moshi Timber Utilisation Research Centre and TAFORI which are available in TAFORI National Forest Library

Forest Utilisation Research

Wood based forest products research

Before 1980 wood utilisation properties of indigenous tree species were tested and different technical notes were produced (Bryce, 1967). About 250 timber tree species out of more than 700 species in Tanzania have been studied for their physical properties, machining and strength properties, suitability of wood for splints and Match boxes, suitability for plywood manufacture, wood movements, wood treatment, wood anatomy and the natural durability of the wood. This led to advancement in technologies in wood machining and mechanics in Tanzania and the results of all wood tests are presented in Technical Notes and the text book of the commercial timbers of Tanzania (Bryce, 1967; Chihongo, 2000). Research in timber engineering culminated into production of small text book titled "Kupasua Mbao" prepared purposely for small scale timber producers (Flamwell, 1964), Timber engineering hand book and Forest products bulletin was also prepared with strength properties of 77 tree species (Malde, 1970). The produced text books are very useful tool to wood dealers locally and globally to date. Recently the utilisation properties of some lesser known timber species had been tested and recommendations were made on the quality of the wood to the end users (Mbwambo *et al*., 2007; TAFORI, 2011). Research on wood anatomy was conducted and produced a technical note on hard wood lens key for Tanzania Timbers (Chunsi and Chinula, 1978; 1979) which is useful teaching materials in Forest colleges in Tanzania. Peeling and gluing characteristics of more than 15 timber tree species used in Tanzania wood industry have been determined (Chunsi and Chinula, 1979). The results were very useful tool in the development of plywood industry in Tanzania.

Research on the resistance of various timber tree species to preservative impregnation were carried out in Tanzania until early 1980s and field trials of wood preservation were established in different sites in the country. Different chemicals have been recommended for the control of termites and fungi which are used to date and the details are provided in Technical Note available in the National Forestry Library housed at TAFORI. A Code of Practice for Wood Preservation in Tanzania with schedules showing timbers preservation schedules developed and still in use in the wood treatment plants to date. During 1980s TAFORI under DFUR provided technical advice to power and telegraphic transmission companies in Tanzania on the quality of the poles by assessing the quality of chemicals used and its penetrability into wood. The results enabled the companies to use the well treated poles which are in-service to date (Murira, 1985). Research in tree species suitability for manufacturing splints and match boxes has been conducted over the past five decades. The research has been useful for the development of match box industries in Tanzania.

Research also was done on marketing of fuel wood especially charcoal and sawn-wood in Arusha, Moshi and in Dar es Salaam (Kimario, 1979; Mbwambo *et al*., 2008; Kapinga *et al*., 2009; TAFORI, 2012). The results help the government to know the trend of fuel consumption in these towns and the marketing chain of sawn-wood from plantations and natural forests of Tanzania. The dissemination of Cassamance technology in charcoal production to charcoal makers was conducted in Kibaha, Mvomero, Moshi Districts, Morogoro rural and Bagamoyo districts so as to increase the recovery. The Cassamance technology was adopted by charcoal maker in these districts (Kimario, 1980; TAFORI, 2010; 2012) with recovery rate of 30%.

Non-timber forest products research

Forests provide also non-timber forest products (NTFPs) which are often neglected in the forest products trade records. The extent of harvest and contribution of these products to the rural economy is not understood. Large amounts of indigenous tree medicines, aromatic plants like sandalwood, orchids, gums, resins, oilseed and fruits are harvested from the forests and form important part of community socio-economic activities. Research was conducted in medicinal plants, fruits, vegetables and gums in various part of Tanzania in order to identify and document some of the valuable forest products apart from wood that are used by local people (Kimario, 1984, Mbwambo *et al.*, 2010; TAFORI, 2012). The results indicated different valuable NTFPs are available in the forest and can be utilised in a sustainable way to reduce the poverty among the Tanzanian community. The findings recommend the sustainable utilisation of NTFPs through domestication of the prominent and useful tree species and herbaceous plants. Capacity building on processing, packaging, proper storage and marketing of NTFPs was also done to the communities living adjacent to Forest Reserves.

Forest operations research

Forests in Tanzania have suffered from different types of disturbances for years. Research conducted on timber harvesting wastage in Tanzania forest plantation found that timber harvesting techniques are not followed as results some wood are left as stumps and others left unprocessed hence less recovery of wood (Bakari *et al.*, 2006; Balama *et al*, 2005). These studies recommend the proper felling techniques, the proper utilisation of wood left over through making briquettes, the use of proper saw mill and discouraging the use of Chainsaw in processing log into timber. Investigation was conducted to ascertain the causes of death to some tree species and bamboos in natural forest and in plantations (TAFORI, 2009; 2010; 2012). The results indicated that Camphor in Chome and Grevillea in Meru forest plantation dead due to fungal attack and the Bamboo in Kilolo died due to massive flowering. The recommendation made was to enrich the areas by planting fast growth indigenous species for Chome and for Kilolo allow natural recovery of vegetation and for Meru plantation to remove the affected trees. Ecological survey at Bunduki Gap, Uluguru Nature Reserve revealed that there are 44 tree species dominating the area (TAFORI, 2010). Study on effect of pine woolly aphids *(Pineus pini)* on quantity of *Pinus patula* conducted by Rwamputa, (1987) indicated that there is cummulative decrease in volume by 82% for the infested pine.

Challenges facing the forest utilisation research

Inadequate staff; lack of modern laboratory equipment and shortage of expertise personnel in forest engineering and wood science.

Conclusion

Researches conducted under the Directorate of Forest Utilisation and published in different Text Books, Hand Books, Technical Notes and Journals are useful to forest managers and decision makers. Our stakeholders are encouraged to make good reference of these researched materials for sustainable forest management.

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HEARTWOOD, SAPWOOD AND BARK PROPORTIONS OF 83 YEARS OLD *Olea capensis* GROWN IN MERU FOREST PLANTATION, TANZANIA

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Abstract
A study on heartwood, sapwood and bark proportions of 83 years old *Olea capensis* (Knobl.) was carried out in May 2013 in Meru forest plantation in Tanzania. Data was collected from 5cm thick disks cut at 1.3m, 50% and 75% of the total tree height from 32 randomly selected defects free trees. Collected samples were labelled to indicate tree number and position in the tree and were immediately wrapped in polythene bags (to prevent moisture loss) and transported to the wood utilization laboratory at Moshi Timber Utilization Research Centre, Tanzania for laboratory work. The proportion of heartwood, sapwood and bark were measured by a scaled ruler. Analysis of Variance (ANOVA) in Minitab 16 statistical package was used to determine significant differences in proportion between heartwood, sapwood and bark. Results showed that the proportion of heartwood was very high followed by sapwood and bark was the least at all tree height levels. These proportions differed significantly ($P < 0.001$) with one another. It is concluded that the high proportion of heartwood makes the species very durable and resistant to insects attack. However, some more research is needed on the same species at a younger age and different growing conditions.

Keywords: *heartwood; sapwood; bark; proportions, Olea capensis (Knobl.), durability*

Introduction

Olea capensis (Knobl.) (also known as Black Ironwood, East African olive and Loliondo) is an African tree species belonging to the Olive family (Oleaceae). It is widespread in Africa, being found almost throughout Africa south of the Sahara from the east in Somalia, Ethiopia and Sudan, south to the tip of South Africa, and west to Cameroon, Sierra Leone and the Islands of the Gulf of Guinea (Orwa *et al*., 2009). In Tanzania, the species is commonly found in the dry upland forests of the Southern Highlands, Usambara, Meru and Kilimanjaro Mountains (Mbuya *et al*., 1994; Bryce, 2000). It grows well in areas within an altitude of 800-2600 m, mean annual rainfall of 800-2500 mm, mean annual temperature of 14-18^{o}C and deep, loamy and fertile type of soil (Orwa *et al*., 2009). It is used as fuelwood, timber, fodder and the bark is used in local medicine (Hines and Eckman, 1993).

The major macroscopic elements of wood that determine its utilization potentials are the heartwood, sapwood and bark proportions (Ogunwusi, 2013). The heartwood is the wooden portion inside a tree where production of life cells has ceased or food reserve materials have been removed (Anonymous, 1983; Miller, 1999). The International Association of Wood Anatomists (IAWA) define heartwood as the inner layer of wood in the growing tree that has ceased to contain living cells and in which the reserve materials such as starch have been removed or converted into toxic substances refereed to as extractives (IAWA, 1964). With the age of the tree, parenchymal cells die losing their reserve substances, and the wood remains protected by a multicomponent organic complex (heartwood substances) (Nawrot *et al*., 2008).

Heartwood, sapwood and bark proportions vary considerably between wood species. They normally define the volume of usable portion of wood, its durability and utilization potentials (Ogunwusi, 2013). The heartwood determines the durability of wood and its presence has been associated with characteristic for high end products. It has properties that significantly influence the usefulness of wood notably its resistance to deterioration by insects, marine borers and microorganisms (Taylor *et al.*, 2002). Information on heartwood percentage in wood species promotes its acceptability by end users. In some species, heartwood may be distinguished from sapwood by a darker colour, lower permeability and increased decay resistance. Heartwood often has different moisture content than sapwood. Sapwood is defined by IAWA (1964) as the portion of wood that contains living cells and reserve materials. It contains wood that is part of the transpiration stream of the tree and it generally has high moisture content. Its permeability is facilitated by unaspirated and unencrusted pits. It contains few toxic extractives and is generally susceptible to decay (Taylor *et al.,* 2002). The primary role of sapwood is to conduct water from the root to the crown. It also serves as a storage site for water, energy reserve materials such as starch (Hillis, 1987; Ryan, 1989) and as a site for living cells that can respond to injury through production of more tissues or defensive compounds (Boddy, 1992). Sapwood is also responsible for storage and synthesis of biochemicals (Wiedenhoeft and Miller, 2005).

The tree bark on the other hand makes the outer part of the tree protecting the cambium and also retarding the loss of water. It protects the tree from extreme temperatures and intense sunlight. The bark is porous and helps the tree breathe and also protects it against disease organisms. While the bark proportions vary considerably between different tree species, it also varies within species. Perez and Kanninen (2003) reported the bark proportion in *Tectona grandis* to vary between 14 and 37% of the total tree volume. Therefore the heartwood as well as bark content (and indirectly the sapwood) are determinant quality characteristics and proper attention has to be given in order to find linkages between management systems and their formation (Taylor *et al.*, 2002).

There are a few studies on tropical species that concentrated on heartwood, sapwood and bark proportions. Most research studies on tropical hardwoods are directed at determining the physical, chemical and mechanical properties of wood species (Ogunwusi, 2013). This study aimed at narrowing the gap by determining heartwood, sapwood and bark proportions of *Olea capensis* growing in Meru forest plantation in Tanzania.

Materials and Methods

Study area

Data was collected from *O. capensis* trees planted in 1930 at Narok, about 13.8 km North of Arusha town at an altitude of 1,770 m above sea level on the Southern edge of Meru Forest Reserve on a slight slope. The area receives mean annual rainfall of 1,778 mm which is highest in April and May. Rains are well distributed hence exposing trees to very low moisture stress. Generally the area has cool temperature with an average of 21°C. According to Hines and Eckman (1993), the favourable temperature for *O. capensis* growth falls between 14 to 18°C. This means Narok is not very far from the respective favourable temperatures. The area has rock volcanic soil brown in colour, powdery, deep and slightly more plastic at depth. Originally the area was covered with upland forest of mixed species including *Croton sp., Rauvolfia caffra, Neobotonia sp*. and *Entandrophragma sp*. The stand was thinned from 680 to 360 stems per hectare.

Data collection
A total of 32 defect free trees were selected at random marked and felled. For each felled sample tree, three 5cm thick disks were cut at 1.3m, then at 50% and 75% of the total tree height. Samples were labelled to indicate tree number and position of the sample (disk) in the tree. They were immediately wrapped in polythene bags (to prevent loss of moisture) and transported to the wood utilization laboratory at Moshi Timber Utilization Research Centre, Tanzania where laboratory work was carried out. The proportion of heartwood, sapwood and bark were measure by scaled ruler in the laboratory.

Data analysis
Analysis of Variance (ANOVA) in Minitab 16 statistical package was used to determine significant differences in proportion between heartwood, sapwood and bark.

Results and Discussion
The mean proportions of heartwood, sapwood and bark of *O. capensis* at different height levels are as shown in Table 1. The proportion of heartwood was very high followed by sapwood and bark was the least at all tree height levels (i.e. at 1.3 m, 50% and 75% of the total tree height). The proportions of these three portions differed significantly ($P < 0.001$) with one another at all height levels. The proportion of heartwood decreased as tree height increased while proportions of sapwood and bark increased as tree height increased. The presence of high portion of heartwood is associated with the durability of wood and characteristic of high end products. This is the property which classified the species to be widely used in railway sleepers, wagon woods, bridge construction and for flooring blocks. Orwa *et al.* (2009) also reported that the species is good for fuelwood from which excellent charcoal can be made. The good proportions of sapwood recorded (22.83%, 32.04% and 40.67% at 1.3m, 50% and 75% of the total tree height respectively implies that the tree has enough area (portion) for water conduction from the root to the crown and enough storage site for water, energy reserve materials such as starch and other living cells. This could be one of the reasons as to why the trees survived for many years (83 years).

Table 1: Mean length (proportion) of the heartwood, sapwood and bark of *Olea capensis* grown in Meru forest plantation in Tanzania

Tree height levels	Heartwood	Sapwood	Bark	F-Value	P-Value
1.3m	15.34 (70.76%)	4.95 (22.83%)	1.39 (6.41%)	$F_{2,93} = 126.24$	$P< 0.001$
50%	9.73 (60.66%)	5.14 (32.04%)	1.17 (7.29%)	$F_{2,93} = 85.14$	$P< 0.001$
75%	5.87 (50.47%)	4.73 (40.67%)	1.03 (8.86%)	$F_{2,93} = 37.65$	$P< 0.001$

Results trend obtained in this study follows the trend reported by Ogunwusi (2013) who reported the proportions of heartwood, sapwood and bark of *Albizia zygia* to be 49.19%, 40.04% and 10.77% respectively. However, the proportion of heartwood in *O. capensis* at all tree height levels were higher than that of *Albizia zygia* while lower for sapwood at 1.3m and at 50% and lower for bark at all tree height levels. The reported results of old (83 years) *O. capensis* trees might be different from similar trees of different ages. This is because, the quantitative ratio of heartwood to sapwood in tree stems depends first of all on the age of trees, climatic and soil conditions, the height at which the analyzed stem cross-section is located and on the crown size (Nawrot *et al*., 2008). Considering *O. capensis* grown in Meru one might expect different results for the same species from different locality. However, various authors report different results on heartwood contents with respect to site. Perez *et al.* (2004) reported that no clear differences in heartwood content could be observed between trees of similar age from dry and wet zones. While Cordero and Kanninen (2003) reported that heartwood proportion differed significantly ($P<0.05$) among climatic zones: 'wet' sites producing less heartwood than 'dry' sites.

The high proportion of heartwood in *O. Capensis* makes it durable and resistant to termites (Mbuya *et al*., 1994). Generally, wood with high percentage of heartwood can be naturally durable compared with wood species with lower percentage of heartwood. This is from the fact that, heartwood contains high amount of extractives which are the most important factor in determining the natural durability of wood (Hillis, 1987). It makes the wood resistant to deterioration by insects, marine borers and microorganisms (Taylor *et al*, 2002). Heartwood is less attractive than sapwood for some pathogens as it lacks requisite nutrients. For example, starch is required for successful reproduction of *Lyctus* beetles that inhabits wood. These insects hardly ever attack heartwood which is free of starch (Taylor *et al*, 2002). The high durability of *O. capensis* is also reported by Bryce (2000).

Conclusions and Recommendations

It is concluded from the study that *O. capensis* has high proportion of heartwood which makes it very durable. With the present results it is also conclusive that Meru is the best growing site for the species. However, some more research need be conducted on the same species at a younger age and different growing conditions.

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DETERMINATION OF BASIC DENSITY OF V*itex keniensis* GROWN IN KILIMANJARO, TANZANIA

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Abstract

The study was done to determine wood basic density (BD) of *Vitex keniensis* (Turill) synonymous *Vitex fischeri* (Cürke) grown in natural forests in the southern slope of Mount Kilimanjaro. Five trees of good form were systematically selected. Disk samples for basic density measurement were taken to laboratory for testing. Results showed that, basic density for *Vitex keniensis* in radial ranged from 392.15 to 457.52 kg m^{-3} and axial from 390 to 476 kg m^{-3} with the average of 440.15 ± 4.9 kg m^{-3}. Basic density in radial direction for *V. keniensis* was found to be higher at the wood near the pith; then decreased and increase again in intermediate wood and decreased in wood closely to the bark. The difference in basic density across the radial direction was not statistically significant ($p > 0.05$). In axial direction basic density was found to be higher at the bottom of tree as compared to the top. Generally there was significant decrease in basic density ($p < 0.05$) towards the top of the tree stem. The wood from this tree species can be classified as medium wood and fairly strong. It was recommended that, wood from *V. keniensis* can be used for light to medium works. More research is needed on its mechanical and anatomical properties in order so to relate with basic density obtained.

Keywords: *Vitex keniensis, Wood disk, Basic density, Wood variation, Green volume*.

Introduction

Vitex keniensis Turill. is an indigenous deciduous tree species belonging to the family Verbenaceae (Linn) commonly known as Meru Oak (Engl), other names are Moru or Muuru (Meru) and the Swahili name is Mfuu (Mbuya *et al*., 1994). It is a valuable timber tree found on the eastern slope of Mount Kenya. The tree is fairly fast growing and reaches the height of up to 30m with rounded crown, clear straight ball and the bark has pale brown to dark brown colour. *V. keniensis* generally grow well at altitude of 1500 m a.s.l. but in Kilimanjaro thrive well between 1500 to 1850 m a.s.l. Locally the species is common with *Commiphora eminii* on thicken rocky hills in Shinyanga and Lake Victoria in Tanzania. This tree prefers deep sandy loam soil (Mbuya *et al*., 1994).

Wood density is considered as an important indicator of general wood quality; including timber strength and stiffness (Ishengoma and Nagoda, 1991). Improved wood density can significantly increase the recovery of high-grade lumber, as assessed by machine stress grading (Bryce, 1967). Density normally varies within a tree, increasing from pith to bark and is strongly influenced by geographic location, site fertility, age and genetics (Hamza *et al*., 2001). Wood is a complex composite material that can contain varying amounts of water absorbed within the fibre. Therefore density needs to be defined in relation to standard conditions, such as ‘green’, ‘air-dry’, ‘oven-dry’ or ‘basic’. The most common (and useful) expression is the basic density, which is calculated as the oven-dry weight divided by the green wood volume, expressed in kg m^{-3} (Bryce, 1967). Basic density varies greatly within and between species, being strongly influenced by geographic location, site fertility, age and genetics. It can also be influenced by silviculture (Ishengoma and Nagoda, 1991; Hamza *et al*., 2001). *Vitex keniensis* or *Vitex fischeri* grown in Kenya found to have basic density values ranging from 430 – 570 kg m^{-3} at 12 moisture content (M.C) (www.database.prota.org). Global wood density database indicated *Vitex keniensis* to have basic density of 469 kg m^{-3}at 12% M.C www.dnp.go.th

Objectives

The overall objective of the study was to determine basic density of 43 years old *Vitex keniensis* grown under montane forest at Barankata I in Kilimanjaro Catchment Forest Reserve. The results from this study enable researchers to give recommendation on utilisation properties of this tree species in Tanzania and promote its production in forest plantation. Specifically the study aimed to determine wood colour and basic density at 12% Moisture content both radial and axial position.

Materials and Methods

Study area description

Samples of *Vitex keniensis* were collected from a trial plot of Tanzania Forestry Research Institute in Barankata I located on the Southern slope of Mount Kilimanjaro. The trial plot is located at latitudes 03^{o}10’10.5”S and longitudes 39^{o}16’58.4”E and at an elevation of 1854 m a.s.l. The area received annual rainfall range from 1550 – 2000 mm and annual temp 16^{o}C – 18^{o}C (Lovett 1993). The vegetation around the plots is dominated by the open canopy of *Ocotea usambarensis* and *Macaranga kilimandscharica* on the upper canopy with below canopy occupied by *Ocotea usambarensis* suckers, young *Macaranga kilimandscharica* and Herbaceous weeds were composed of many regenerants of *Vitex keniensis* and *Acrocarpus flaxinifolius.* Other species found in this area include *Albzia gummifera, Podocarpus latifolius* and the ground is mainly covered with ferns (Lambriechts *et al.*, 2002; Malimbwi *et al.*, 2001; Katigula 1992) The plot is at the gentle slope and the soil generally is loam with reddish colour and has deep to very deep depth with pH value range from 4 - 4.6 (Lovett& Pocks 1993).

Sample collection

Sampling

Five trees of good form were systematically selected from the plot and measured for diameter at breast height (DBH) and the total height was measured after the tree felled on the ground. Four wood disks measuring 5cm thick were cut at 1.3 m, 30%, 60% and 90% of total tree height. The disks were labelled and brought to Laboratory for sample processing at Moshi Timber Utilisation Research Centre (MTURC).

Sample preparations

From the air dried disk, two wedge shaped sample, measuring about 45 degree was cut from the pith to the bark. From the wood wedges 10 strips were cut and serially labelled as P1 to P5 where wood near the pith recorded as P1 and wood near to the bark as P5. These strips were used for the determination of the average basic density of the tree in axial position as well as in radial directions.

Laboratory procedures

Basic density determination was done in accordance with BS 373 1957; Mbwambo *et al.*, (2007) procedures in which green volume and Oven dry weight for each sample were calculated.

Green volume determination

Specimens were first soaked in distilled water until they attained green volume condition. Then the green volume was obtained in accordance with Archimedes Principle using distilled water as displacement liquid. Then green volume (V) was calculated by dividing mass (M) of water displaced to the density (D) of distilled water which is $1g/cm^3$. The results obtained from the division are equal to the volume of the wood samples immersed in the water.

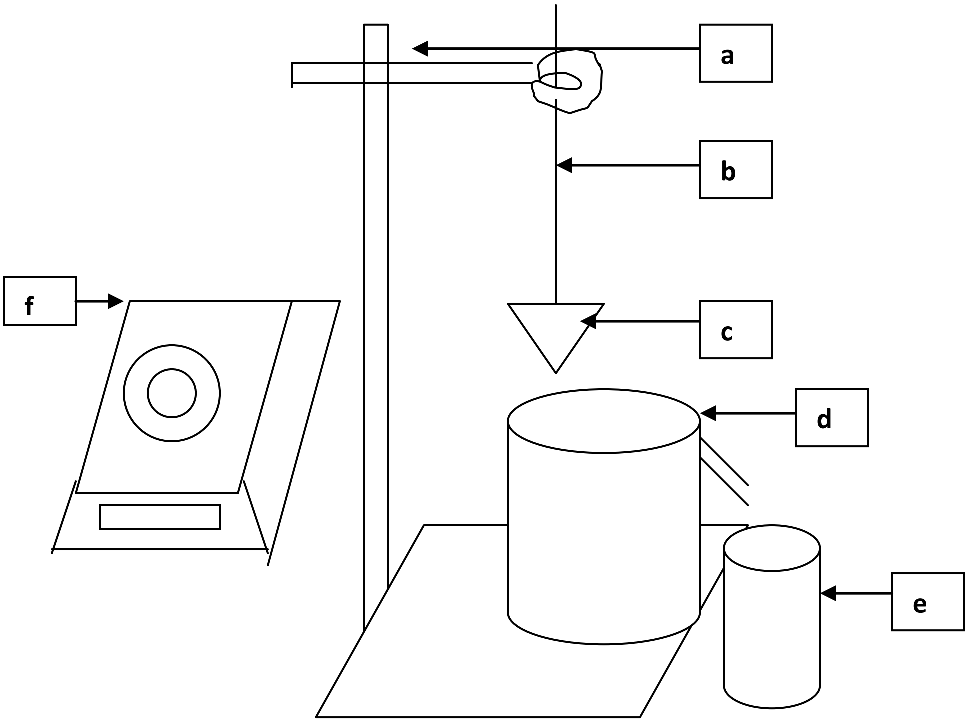

Figure 1: Example of equipment for determining the green volume of irregular wood samples

(a) Retort stand for holding sample (b) Thin wire to hold wood sample

(c) Wood sample with irregular shaped (d) Eureka can

(e) Beaker with known weight (f) Sensitive balance

Oven dry determination

This was done by drying the specimen in an oven at temp of 102 ± 3^0C until a constant weight was recorded. The specimens were cooled in desiccators, reweighed and the dry weight in grams was recorded.

Basic density (BD) obtained by dividing oven dry weight (M) (g) to green volume (V) (cm^3)

Data analysis

Microsoft excel spreadsheet was used for all descriptive statistics. Analysis of Variance (ANOVA) was used to determine axial and radial basic density variation within a tree species.

Results and Discussion

Basic density is considered to be the key indicator for most strength properties of timber (Ishengoma and Nagoda, 1991). This study showed that average basic density for *Vitex keniensis* was 440.15 ± 4.9 kg m^{-3} ranging from 392.15 to 457.52 kg m^{-3} in radial direction (Table 1).

Table 1: Average basic density in radial direction for *Vitex keniensis*

Position from pith	Basic density (kg m^{-3})
Wood at pith (P1)	440.78
Intermediate wood (P2)	392.15
Intermediate wood (P3)	427.43
Intermediate wood (P4)	457.52
Wood near the bark (P5)	446.86

During data analysis the average basic density for a single tree in radial direction is the same as in axial direction but the differences observed when considering wood in section wise the average basic density was different with wood at 1.3 m having more basic density than wood at 60% and 90% of total tree height.

According to Panshin and de Zeeuw (1970) woody with density of 300 kg m^{-3} or less are considered to be light, 360 to 500 kg m^{-3} moderate and above 500 kg m^{-3} heavy. Therefore *V. keniensis* timber can be classified as moderate timbers. The basic density obtained from this study for *Vitex keniensis* 439.92 ± 4.9 kg m^{-3} is different from that of *Vitex doniana* grown in Miombo woodlands of Tanzania 400 kg m^{-3} reported in Bryce, 1967 edited by Chihongo, (1999). The different might be brought by geographic location, site fertility, age and genetics. The average basic density values obtained in this study is within the range of basic density reported in Kenya for the same species with 430 – 570 kg m^{-3} at 12 moisture content (M.C) (www.database.prota.org). Considering the average basic density of other hardwood trees (*Albizia spp, Macaranga spp, Cordia spp, Podocarpus spp and Croton spp*) grown in the same altitude in highland areas like Northern and Southern highland of Tanzania have higher average basic density (Bryce, 1967) than the wood of 43years obtained from *Vitex keniensis*.

Variation in basic density

Radial variation

Radial variation in basic density of *Vitex keniensis* is shown in Figure 2. Basic density increased from pith to the bark but the increase was not significant difference ($F(4,50) = 2.6$ $p > 0.05$). Generally basic density of wood near the pith (P1) was a little bit higher than wood at P2 and P3 but lower than wood at P4 and P5 are closely to the bark. This variation is due to the fact that wood near pith is still immature compared with the preceding wood to the bark (Hamza *et al,* 2001). Also it might be influenced by geographic location, site fertility, age and genetics. It can also be influenced by silviculture (Ishengoma and Nagoda, 1991; Hamza *et al.*, 2001).

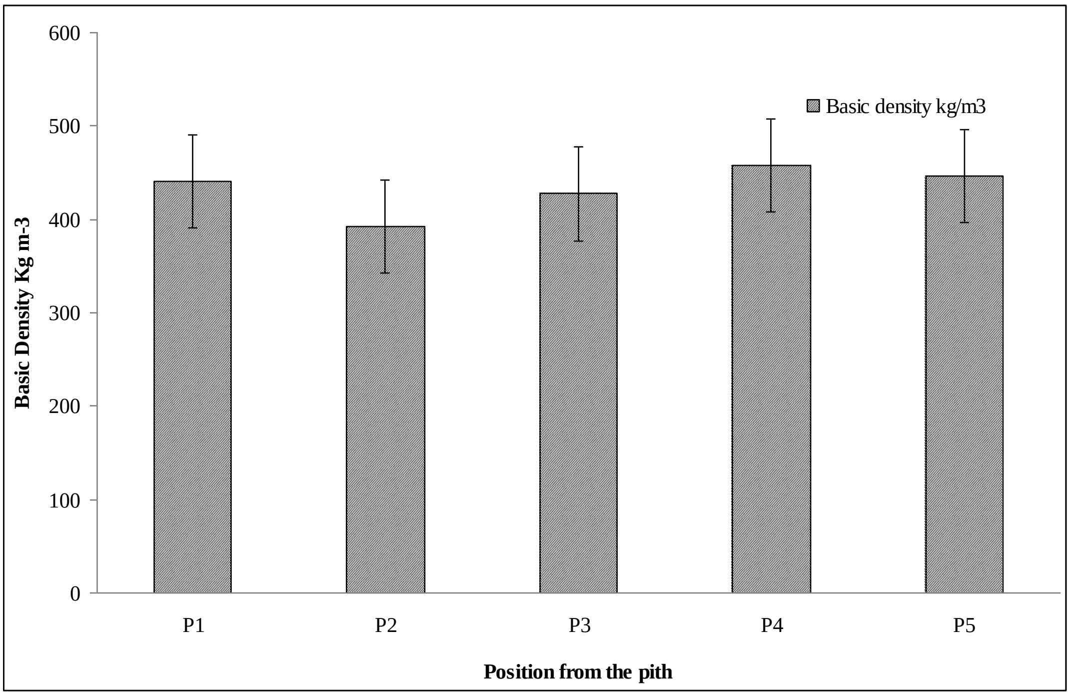

Figure 2: Radial variation in wood basic density for *Vitex keniensis*

The average basic density obtained in radial direction did not follow the same trend as in the study conducted by Gillah *et al.*, (2007) who observed that basic density of *Pteleopsis myrtifolia* being high in areas close to the pith and decreased from pith towards the bark and also in the study of *Uapaca kirkiana* (Gillah *et al.*, 2009) basic density was higher closer to the pith, decreasing outwards.

Axial variation

The average tree height for *Vitex keniensis* was 32m and the section were taken at 1.3 m (4.1%), 9.6 m (30%), 19.2 m (60%) and 28.8 m (90%) of total tree height. The basic density obtained based on this sections in a tree. The results showed that basic density decreased from bottom to top of the tree (Table 2). The decreased was from 476 to 390 kg m^{-3} for *Vitex keniensis*

Table 2: Axial variation in basic density for *Vitex keniensis*

Sampling position	(4.1%) 1.3 m	(30%) 9.6 m	(60%) 19.2 m	(90%) 28.8 m
Basic density (kg m^{-3})	476.08	450.42	427.98	390.70

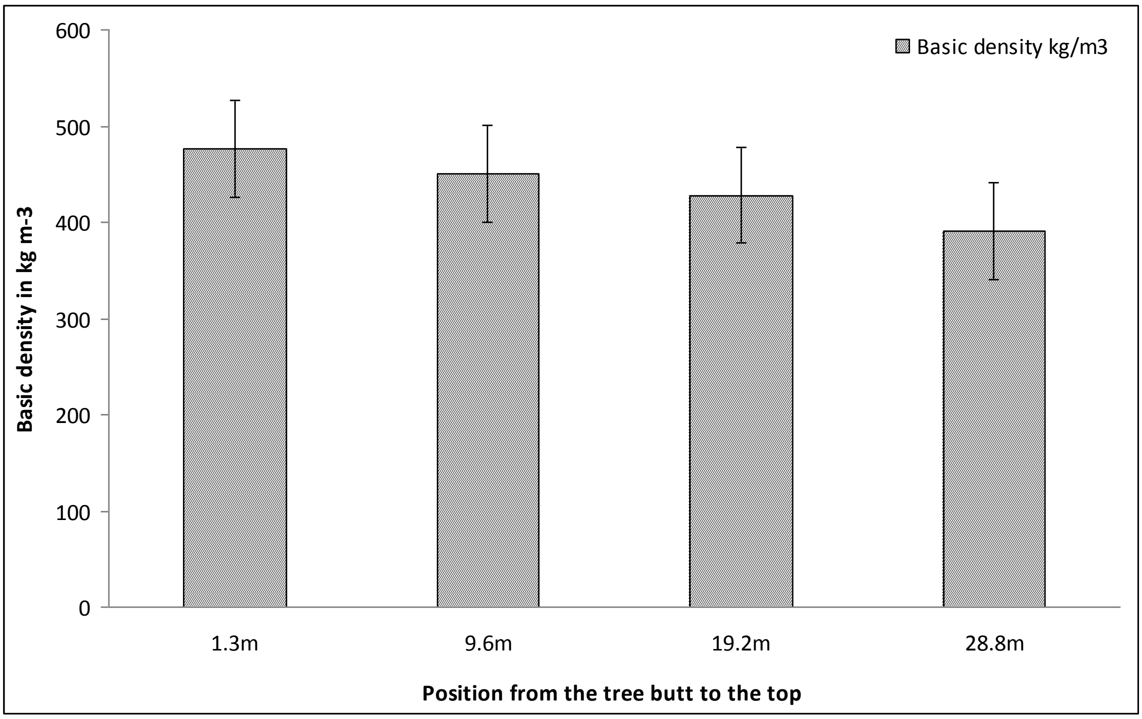

Figure 3: Axial variation in basic density for *Vitex keniensis*

The decrease in axial direction differ significantly from the wood at bottom to the top wood ($F(3,40) = 2.8$ $p < 0.05$). The variation might be due to genetic make up, different in cell differentiation along the tree trunk and accumulation of extractives at lower part of tree trunk than at the top where growth is still progressing.

Conclusion and Recommendation

Timber from the lesser known tree species *Vitex keniensis* has the average basic density 439.92 kg m^{-3} then wood classified as fairly strong. The basic density differs in both radial and axial directions. Wood around the pith and that taken at diameter at breast height has high basic density compared to the preceding wood. Therefore wood from the lower log is suitable for area where medium density wood is required; wood near the pith (P2) and wood from the top logs are lighter hence can be utilised in areas need light wood. More research on mechanical properties needs to be conducted so as to relate with the value of basic density obtained in this study.

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BASIC DENSITY OF 43YEARS OLD *Acrocarpus fraxinifolius* GROWN IN THE SOUTHERN SLOPE OF MOUNT KILIMANJARO, TANZANIA

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Abstract
This study was done to determine wood basic density (BD) and its variation in 43 years old *Acrocarpus fraxinifolius* (Wight*)* grown in TAFORI plots at Barankata in the southern slope of Mount Kilimanjaro. A total of four trees of good form were systematically selected from the trial plot and their wood samples tested. The oven dry mass of the samples was obtained by placing the samples in an oven until constant weight was attained. Green volume of irregular shaped wood samples was determined using Archimedes Principles. Basic density was obtained dividing the oven dry mass by its green volume. Results showed that, basic density for *A. fraxinifolius* ranged from 435 to 578 kg / m^3 with the average of 517 ± 5.45 kg / m^3. Basic density in radial direction for *A. fraxinifolius* increased from the pith to the bark and decreased in axial direction from the butt to the top as expected. There were no significant differences ($p > 0.05$) in basic density at 1.3 m and 30% of the total tree height but statistically the basic density differed from wood at bottom to the 90% of total tree height ($p < 0.05$). Wood from *A. fraxinifolius* can be classified as heavy or strong and ranked as medium weight wood. *A. fraxinifolius* can only be used for light to medium works due to its medium basic density. More utilisation properties of this tree species need to be researched for well informed recommendations on the final use of its wood.

Keywords: *Acrocarpus fraxinifolius, Basic density, Radial variation, Axial variation.*

Introduction
Pink cedar tree or shingle tree (Engl) belonging to the family Caesalpinaceae (L: Roxb) and commonly known as Indian ash with its botanical name *Acrocarpus fraxinifolius* (Wight et. Arn) is stately deciduous tree attaining height of 30 – 60 m originates from tropical Asia where it occurs naturally from Nepal, India, Thailand, Southern China and western Indonesia (www.worldagroforestry.org) It is widely planted in tropical America and in tropical Africa. The tree species introduced to Tanzania and grow best in sub montane areas mainly at altitude of 1000 – 1500 m a.s.l. with the red soil and moist climate (Mbuya *et al*., 1994). It has a cylindrical stem free from branches for up to 75% of its total height with thin bark and light grey in colour (www.database.prota.org). The timber from this tree species seems to have whitish sap wood and the heart wood is bright red to brownish red with darker veins and used in (Mbuya *et al*., 1994). Some lesser-known tree species from agroforestry system have been studied, (Hamza *et al*., 2001) work on wood utilisation properties of *Artocarpus heterophyllus* (Lam) and the average basic density was 500 kg / m^3 which were less than that of *Albizia gummifera* 640 kg / m^3 grown in the same area and 545 kg / m^3 in other parts of Tanzania. *A. fraxinifolius* is one of the lesser-known timber species grown in plantations and in agroforestry system in Tanzania. The climatic condition and soil where the tree grow in Tanzania is quite different from the country of origin therefore there is need of knowing its utilisation properties. There no/less information on its wood quality at different ages. This study aimed to determine basic density of 43 years old *A. fraxinifolius* grown under moist forest condition (Montane forest) at Barankata I in Kilimanjaro Catchment Forest Reserve, Tanzania

Materials and Methods
Materials

Samples of *Acrocarpus fraxinifolius* were collected from a TAFORI trial plot in Barankata I at the Southern slope of Mount Kilimanjaro in a Catchment Forest Reserve. The trial plot was established 1963 with the aim of measuring growth performance and volume increment of the tree species.

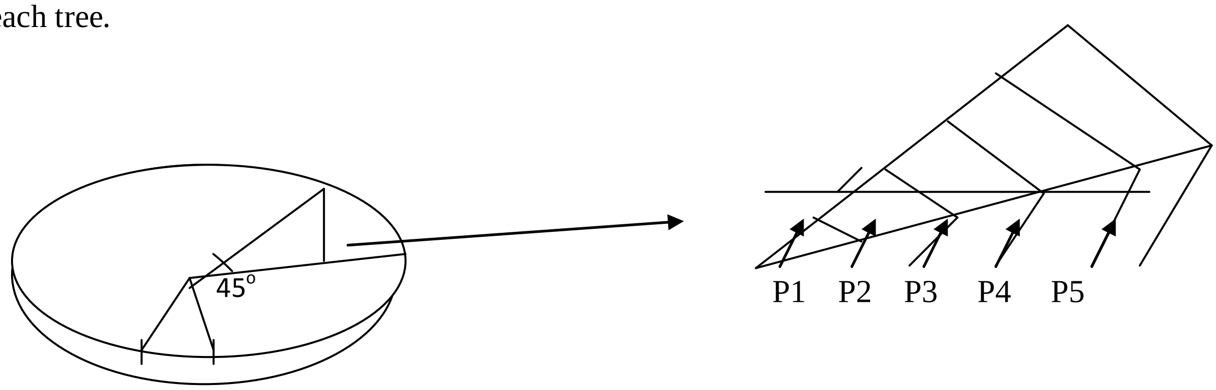
The trial plot is located at Latitudes 03^{o}10’10.5”S and Longitudes 039^{o}16’58.4”E and at an elevation of 1854 m a.s.l. The topography is dominated by gentle slope with andosols soils rich in nutrients and generally the soil is loam with reddish colour and has deep to very deep depth. The forest soils are also full of litter and the pH is 4 - 4.6 (Lovett and Pocks, 1993). The area receives rainfall in a bimodal pattern with short rain Oct- Dec and long rain from April to May and during dry season July to September there is little rain which make the annual rainfall range from 1550 – 2000 mm and annual temp 16^{o}C – 18^{0}C (Lovett, 1993). Vegetation is mainly montane forest characterized by Camphor and Macaranga species in the upper slope of Mount Kilimanjaro.

Methods
Sample collection

Four trees of good form and free from visible defects were systematically selected from each plot and measured for diameter at breast height (DBH) and tree height. Sample trees were felled using chainsaw and the bole height was measured on the ground. From each sample trees four disks measuring 5cm thick were cut at 1.3m, 30%, 60% and 90% of total tree height. The disks were labelled to indicate the species, tree number and position in the stem. The disks were air dried to 12 % moisture content at Moshi Timber Utilisation Research Centre (MTURC) ready for laboratory tests.

Preparation of Samples

Two wedge shaped sample, measuring about 45 degree at the pith running from the pith to bark (Figure 1a) was cut from each disk and 10 strips cut and serially labelled as P1 to P5 for each wedge (Fig 1b). These strips were used for the determination of basic density of the tree as well as it is variation in radial and axial directions. Forty (40) samples were prepared from each tree.



(a) Disc from wood (b) Wedge shaped sample

Figure 1: Section of disc and wedge shaped wood taken for sample preparation

Laboratory procedures

Green volume determination

Determination of Basic density was done in accordance with BS 373 1957; Olsen, 1971 in Mbwambo *et al*. (2007) in which green volume and Oven dry weight for each sample were obtained Green volume in cubic centimetres for each sample was obtained by using water displacement method. All specimens were first soaked in distilled water until they attained green volume condition. Then the green volume was obtained in accordance with Archimedes Principle. The green volume was determined first by determining the weight of water displaced and was calculated by dividing the mass of water displaced by the density of water. The results obtained from the division according to the principles, is equal to the volume of the specimen.

Green volume (V) = M/D……..……. (1)

Where:

M (g) = Weight of water displaced

D (g / cm^3) = Density of water

Normally density of distilled water is 1g/cm^3

Oven dry weight determination

This was done by drying the specimen in the oven at a temp of 102 ± 3^{o}C until a constant weight was attained. The specimens were cooled in desiccators and reweighed. The oven dry weight in grams was recorded.

Basic density calculation

Basic density (g / cm^3) was calculated using the following formula

Basic density (Bd) = Oven dry mass (g) / Green volume (cm^3)……………… (2)

The value obtained in g / cm^3 converted into kg / m^3

Data analysis

Microsoft excel soft ware was used for all descriptive statistics. Analysis of variance (ANOVA) was used to determine axial and radial basic density variation in wood of *Acrocarpus fraxinifolius*

Results and Discussion

Physical properties

Wood colour

The heart wood of *Acrocarpus fraxinifolius* was reddish - pink in colour and the sapwood was observed to have whitish colour. The heartwood can be used for decorative work especially indoor furniture and the sapwood for making crates and beehives.

Basic density

Basic density is considered to be the key indicator for most strength properties of timber (Ishengoma and Nagoda, 1991). The average basic density for *A. fraxinifolius* recorded in this study was 517 ± 5.45 kg / m^3. The lowest value was 435.54 kg / m^3 and the highest was 578.15 kg / m^3 (Table 1). According to Panshin and de Zeeuw (1970) wood with density of 300 kg / m^3 or less are considered to be light, 360 to 500 kg / m^3 moderate and above 500 kg / m^3 are considered heavy and according to FAO wood with basic density range from 401 to 500 kg / m^3 are fairly strong, 500 to 640 kg / m^3 strong, 640 to 800 kg / m^3 very strong and greater than 801 kg / m^3 exceptionally strong (www.fao.org/docrep). Therefore *A. fraxinifolius* timber from 43 years old tree grown in natural forest in Tanzania can be classified as heavy wood and strong. The basic density obtained from this study 517± 5.45 kg

/ m^3 for *A. fraxinifolius* are within the range of basic density of the same species grown in other countries in the world which found basic density of this species to range between 520 to 700 kg / m^3 at 12% moisture content (M.C) (www.database.prota.org). The values obtained in this study are lower than those of most valuable traditional timbers grown in the same locality like *Ocotea usambarensis* (Engl) 577 kg / m^3, *Croton megalocarpus* Hutch 721 kg / m^3, and *Olea capensis* L spp. 881 kg / m^3 but greater than that of *Podocarpus spp* 513 kg / m^3 and *Macaranga kilimandscharica* (Pax) with 449 kg / m^3 at 12% M.C (Bryce, 1967; Chihongo, 1999). These results are relatively similar to average basic density of *Croton microstachyus* Hochst.ex.Del 545 kg / $m^3$and *Albizia gummifera* (Gmel) 545 kg / m^3. Differences in basic density may be caused by factors such as genetically differences, tree age and environmental conditions. The age of the trees tested in this study was 43 years old from Barankata I Kilimanjaro area.

Variation in Basic density for *Acrocarpus fraxinifolius*

Radial variation

The basic density for *A. fraxinifolius* seemed to increase from P1 435.54 kg / m^3 which is the wood near the pith to the intermediate wood P3 with 544.60 kg / m^3, then decrease a little bit at P4 with 531.66 kg / m^3 and increase for the wood near the bark P5 with 578.51 kg / m^3 (Table 1). There was a significant difference between the densities from pith to the outer wood ($F(4,150) = 2.4$ $p < 0.05$).

Table 1: Average basic density in radial position

Position from pith	Basic density (kg/m^3)
Wood near the pith (P1)	435.54
Intermediate wood (P2)	487.95
Intermediate wood (P3)	544.60
Intermediate wood (P4)	531.66
Wood near the bar (P5)	578.51

The wood near the pith showed low basic density compared to the preceding wood from the pith (Table 1). This can be explained by the fact that wood near the pith have more juvenile wood (immature) as compared to the outer wood within the same trunk (Hamza *et al.*, 2001).

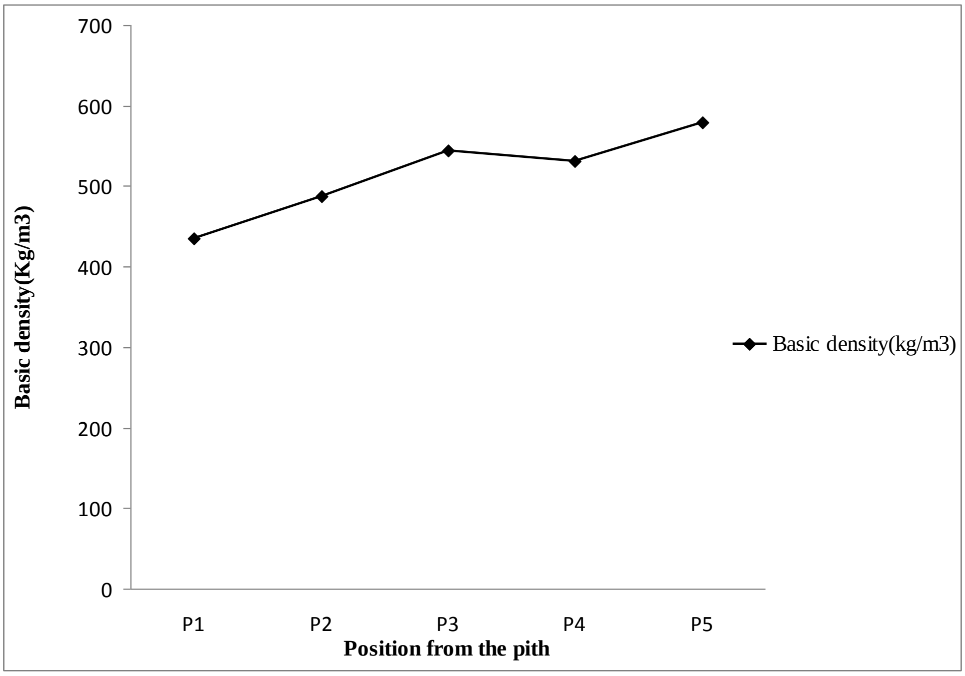


Figure 2: Radial variation in wood basic density for *Acrocarpus fraxinifolius*

The pattern of variation (Figure 2) reported in this study might be attributed by genetic make up of the tree it self and the environment were the tree species is grown but the pattern is contrary to that reported by Gillah *et al.* (2007; 2009) for *Pteleopsis myrtifolia* and *Uapaca kirkiana* and that of *Artocarpus heterophylus* reported by Hamza *et al*. (2001) where the wood at pith has the higher basic density though the wood density obtained were not statistically different. The pattern of variation is similar to what has been reported Montes *et al*. (2007) on *Calycophyllum spruceanum* at the age of 39 months established in three planting zones located in one watershed in the Peruvian Amazon which was increased significantly from pith to bark in all planting zones. This trend might be caused by the proportional of early wood to late wood. The higher the proportional of late wood to early wood the higher the density (Zobel and Van Buijtenen, 1989).

Axial variation

The results (Table 2) showed that basic density for *Acrocarpus fraxinifolius* increase from bottom logs 1.3m to the log taken at 30%, the increase in wood density were not statistically different ($p > 0.05$); then wood basic density decrease to the top of tree and the decrease from the bottom wood (at 1.3 m and 30%) to the top was statistically different ($F(3,152) = 2.7$ $p < 0.05$) with the average values for the second log at 30% recorded as 561.34 kg / m^3 and at 90% of total tree height as 476.95 kg / m^3 (Fig. 3)

Table 2: Axial variation in basic density

Sampling position	1.3 m	30%	60%	90%
Basic density (kg/m^3)	542.49	561.34	494.05	476.95

It was observed that the basic density decreased from butt end to the top of tree stem with the average basic density of 518.71 kg / m^3 being 4.5% lower than that of wood at 1.3m position and 9.2% higher than that of wood at 90% position of the total tree height. Considering the measurement made at the closer to midpoint (at 30%) of the commercial bole, the average basic density was 7.4% more than the average basic density. The variation in basic density from one point to another within a single tree can be used as the criteria for selection of wood for different uses.

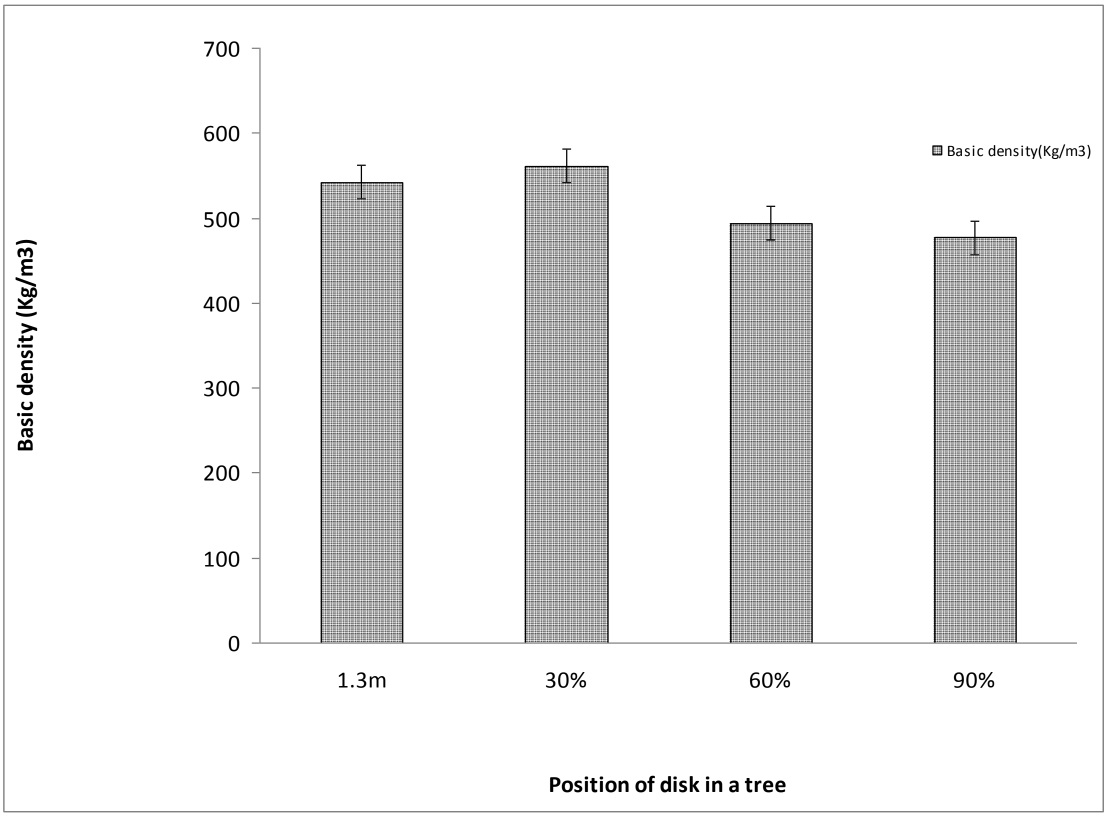


Figure 3: Axial variation in basic density for *Acrocarpus fraxinifolius*

The axial variation patterns obtained in this study may be explained in terms of the amount of extractives present among other factors. At the bottom the heartwood contains high amount of extractives, which contribute to high basic density than wood at the top with large sapwood and less extractive content (Ishengoma and Nagoda, 1991; Dosch and Dinwoodie, 1996). Similar situation was observed by Gillah *et al*, (2007; 2009) on other indigenous tree *Pteleopsis myrtifolia* and *Uapaca kirkiana* though the basic density at different position in a trees were not statistically different. Therefore, wood from the butt log is suitable for use where high density wood is required.

Conclusion and Recommendation

Timber from the lesser known tree species *Acrocarpus fraxinifolius* has the basic density which resembles some valuable tree species. The basic density was also different from the pith to the wood near the bark and from the butt to the top of the trees. Therefore wood from the butt log to 30% of total tree height are suitable for area where medium density wood is required. Wood near the pith is lighter than the preceding wood in tree species tested. This tree species seemed to have wood of good density but with limited uses. *A. fraxinifolius* recommended to be used in making simple boxes, beehives and some indoor furniture using sapwood because it is prone to external factors like weather, insect pest attack but the heart wood can be used in making an outdoor furniture. Research is needed to examine the strength properties of the wood at the same age.

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GROWTH PERFORMANCE OF *Oxystigma msoo* AT RAU FOREST RESERVE IN KILIMANJARO AND IN TRIAL PLOT IN LUSHOTO, TANZANIA

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Abstract
A study to assess the growth performance of *Oxystigma msoo* in Rau Forest Reserve and Lushoto was carried out in May 2009 and annually from 1975 to 2009 respectively. Data were collected from ten-concentric plots of 20 m radius laid in the reserve purposively on where mature *O. msoo* were seen and in two plots established in Lushoto Arboretum and Bush back valley in Lushoto District. A total number of 2950 and 126 trees of *O. msoo* were recorded in Rau Forest and in Lushoto respectively. The numbers of seedlings in Rau Forest were significantly higher than other size classes of *O. msoo* because of over exploitation of saplings resulting from broom supporters making business. There was a significant difference ($p<0.0001$) in mean height between *O. msoo* grown in Lushoto Arboretum and Bush back valley but not in mean DBH. Being one of the most important tree species in Tanzania, it is suggested that better management practices of Rau Forest where *O. msoo* grows naturally should be adopted. Conservation strategies of *O. msoo* through community based practices in the Reserve by using villagers surrounding the reserve should be initiated. This will reduce illegal harvesting of saplings as villagers will be part of the management of the reserve. Encouraging villagers to grow *O. msoo* and other species in their own woodlots to substitute the use of *O. msoo* in Rau Forest is another option of conserving the species. Silvicultural and tree improvement research should be intensified order to increase its productivity.

Keywords: *Oxystigma msoo, growth performance, mean annual increment, threatened species, Rau Forest Reserve, Lushoto.*

Introduction
Oxystigma msoo (Harms) is a legume species in the Fabaceae family. It is a large tree restricted to small areas of remaining moist or riverine forest (Lovett and Clarke, 1998). *Oxystigma* is a genus of about five species whereby four species are native to rain forests of western and central Africa and one, *Oxystigma msoo*, is native to eastern Africa (Tanzania and Kenya) (Rodgers, 1983; Lovett and Clarke, 1998). The tree has an average height of about 47m with pinnate leaves with 4-8 leaflets arranged alternatively on the main leaf-axis. Its flowers are very small, white, in-pubescent, paniculate, spiciform racemes. Its fruits are obliquely and broadly ovate, flattened, keeled at margin (Greenway, 1949). It has grey and slightly flaky bark. The main use of the tree is reported to be plywood (Bryce, 2000).

The tree is common in groundwater forest like Rau Forest Reserve (north-east Tanzania) and believed to occur Pangani and the Tana Delta in South-east of Kenya. In particular, Rau Forest is considered essential to the survival of *O. msoo* because the species is said to occur only in habitats with ground water or riverine forests of 800 m or below which are very limited in East Africa. *Oxystigma msoo* has been reported to be found in Tana River and in limestone forest patches near Mombasa in Kenya and in Tanga and Kilimanjaro Regions (Rau Forest) in Tanzania. Despite its presence in other three localities, *O. msoo* still is considered vulnerable as Tana Forest is threatened by water regime change and firewood felling following upstream river impoundment and limestone forest patches in Mombasa are all encroached. Due to high population pressure, the Rau Forest Reserve is also being reduced in size by cultivation encroachment. Much of this forest is no longer in its natural condition as trees are removed to supply poles and firewood to areas adjoining Moshi Municipality.

The effort to establish indigenous tree plantation in Tanzania has been going on for some years. A number of indigenous tree species including *Khaya nyasika, Olea capensis, Hura creptans, Ocotea usambarensis, Podocarpus usambarensis, Syzigium guineenses* and many others have been tried at Lushoto Arboretum and other plantations at Lushoto (Mugasha, 1996). Two trial plots of *Oxystigma msoo* were established on 1971 for the purpose of assessing the growth performance of this species at plantation level. The seeds planted originated from Rau forest reserve (Kilimanjaro Region), raised at Lushoto nursery and planted at the Arboretum and at the Bush back valley at Lushoto.

The *Oxystigma msoo* species is listed as vulnerable by World Conservation Unit (IUCN) and threatened to extinction under International Trade in Endangered Species (CITES) (Rodgers, 1983). In 1998, IUCN decreed the species to be among the red list of threatened species meaning that the species may become extinct if urgent conservation measures are not taken. Therefore, this study aimed at determining the growth performance of the species in reserve and in the trials and proposing the possible ways of conserving it before its extinction.

Materials and Methods

Study site

Rau Forest Reserve is located at 3°23' S and 37°22' E which is 3 km South East of Moshi Municipality, Kilimanjaro Region in Tanzania. It has an area of about 620 hectares. The reserve is on the gentle south facing alluvial base of Mount Kilimanjaro, at an altitude of between 730 and 765 m. The mean annual rainfall is estimated at 870 mm/year. It has two rainy seasons' namely short rains in December and long rains from March to May. Hot season reaches its peak in January – February with a mean maximum temperature of about 34°C and the coldest month reaches its peak in July at 24°C (Bakari, 1995). The soils are named as fluvisols and nutrient rich gleysols on alluvial sand (Zandra and Sari, 1994). The Forest reserve is famous for two rare tree species, *Oxystigma msoo* and *Lovoa swynnertonii*. Rau Forest is considered essential to the survival of *O. msoo* because the species is said to occur only in habitats with ground water or riverine forests of 800 m or below (Rodgers, 1983). Two trials were established at Lushoto Arboretum and the Bush back valley both located in Lushoto District with 100 *O. msoo* trees each. Lushoto District is located in the northern part of Tanga Region it lies within 04^{o} 25' – 04^{o} 55' latitude South of Equator and 30^{o} 10' – 38^{o} 35' longitude East of Greenwich. The District is mountainous with meandering valleys and an elevation that ranges from 500 to 1700 metres above sea level. It has a montane climate with a maximum temperature ranging between 20 °C and 25°C and a minimum temperature range of 15^{o} C to 21 °C. Rainfall is extremely variable, ranging from 12mm to 1500mm per year (Janowski *et al.*, 2004)

Sampling and data collection

As the tree grows in patches, purposive sampling was adopted whereby a plot was established where a mature *O. msoo* was seen. Ten circular plots of 20 m radius each were established within the reserve. Within the established plot, diameter at breast height (DBH) (cm) and Height (m) of *O. msoo* were measured. The measured *O. msoo* were classified as mature (DBH > 10cm), poles (5 < 10cm DBH), saplings (2 < 5 cm DBH) and seedlings (< 2cm DBH or 150cm Height). At Lushoto plots, data were collected annually from 1975 to 2009 from all *O. msoo* trees except boundary tress i.e. 72 and 54 trees at Lushoto Arboretum and Bush back valley respectively. Parameters measured were DBH (cm) and Height (m). Suunto, caliper, tape measure, GPS and camera were used for measuring height, DBH, location and taking pictures respectively.

Data analysis

Data were analysed using Minitab 12 software. Analysis of variance (ANOVA) was used to determine significant differences in mean numbers between seedlings, saplings, poles and mature O. msoo within the Reserve. T-test was employed to determine significant differences in mean DBH and height of O. msoo between Arboretum and Bush back valley. Mean Annual Increment (MAI) were obtained by subtracting the two Mean DBH and heights measured at the age of 37 and 38 years.

Results and Discussion

Rau Forest Reserve

The distribution of *O. msoo* species in Rau Forest Reserve is presented in Figure 1. A total of 2950 trees of *O. msoo* were recorded in Rau Forest Reserve whereby over 83% of the recorded *O. msoo* was dominated by seedlings. The results show that the number of *O. msoo* decreases with increase in age with the mean number of 246, 26, 13 and 10 for seedlings, saplings, poles and mature trees per plot respectively. The analysis of variance showed that there was a significance difference ($F_{3,36} = 34.89$; $p < 0.0001$) between size classes. Mean Based on Pooled Standard deviation at 95% confidence interval (CI) showed that seedlings were significantly higher than other size classes. *Oxystigma msoo* in the forest agrees with Chidumayo (1997) who reported that the distribution of stems per hectare in natural forests follows the usual reversed J-shaped curve which implies the availability of many young trees than mature trees. However, there was a limited recruitment from seedlings to saplings because of over exploitation of saplings resulting from broom supporters making business. This overexploitation of saplings is extensively done and is resulting to danger of *O. msoo* in the reserve. Saplings are capable to grow to poles if crooked or if they are near by the road where it becomes difficult to do exploitation. The mature trees recorded in the forest are few and very big having DBH 180 – 190cm (Plate 1) a sign of being over mature. Strict restriction on exploitation of saplings for broom making is a prerequisite to allow better regeneration of the species as it is an endemic in Rau. Other noted drawbacks of *O. msoo* in Rau were climbers, *Lantana camara* which acts as parasite and hinders/depresses growth of the tree.

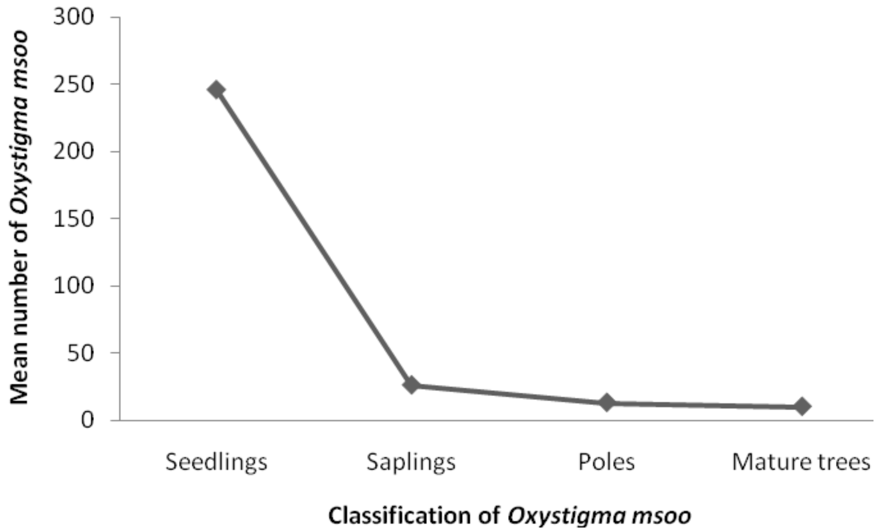

Figure 1: Distribution of *Oxystigma msoo* in Rau Forest Reserve

Plate 1: Mature *Oxystigma msoo* in Rau Forest Reserve, Kilimanjaro, Tanzania.

Lushoto Arboretum and Bush back valley trial plots

A total of 126 *O. msoo* trees were measured with 72 trees from Arboretum and 54 trees from Bush back valley. The results revealed that the trees at the Arboretum have MAI of 0.46cm and 0.43m for DBH and height respectively and 0.42 cm and 0.34m for DBH and height respectively for Bush back valley. *Oxystigma msoo* in the trial plots had the mean DBH of 17.37 cm and 15.38 cm and mean height of 16.26m and 13.05m at the Arboretum and Bush back valley respectively at the age of 38 years. There was a significant difference in mean height ($p < 0.0001$) between *O. msoo* grown in Lushoto Arboretum and Bush back valley but not in mean DBH ($p = 0.216$). The results show that trees grown at Arboretum have both higher DBH and height than that grown at Bush back valley. This difference might be attributed to spacing effect as *O. msoo* were planted at Arboretum with spacing of 2.5 m x 2.5 m while those at Bush back valley with a spacing of 2.0 m x 2.0 m. As the spacing increases between trees competition decreases and girth increment increases. Tree spacing plays an important role in tree growth as it influences the quantity and quality of wood produced (Zobel *et al*., 1987; Evans, 1992). Similarly the differences could be due to site effect as Arboretum is located at sloppy areas with clay loam soil whilst Bush back valley is located in a water logged area with clay soil. The growth rate of *O. msoo* is low compared to that of Japanese Camphor grown in Lushoto with age of 34 years, having 29.4 m mean dominant height and mean Dbh of 34.7 cm, corresponds to about 0.9 cm MAI in height and over 1.0 cm MAI in Dbh (Mugasha, 1978a). Similarly, Anon (1963) recorded a relatively high MAI of a 36 years old stand of East African Camphor (*Ocotea usambarensis)* in South Kilimanjaro with a MAI girth at breast height of 0.6 cm Dbh. This difference among other factors is due to species differences. At the age of 22.7 years *O. msoo* at Arboretum had MAI of 0.55cm and 0.57 m for DBH and height respectively. The results show that, MAI decreases with age suggesting that the competition becomes severe as age increases and girth increment falls below. The same was observed by Anon (1963) on the growth rates of *O. usambarensis* in South Kilimanjaro and West Usambaras and by Mugasha (1978b) on the growth of *Cephalosphaera usambarensia* at Amani and Kwamkoro. Generally, *O. msoo* performs well under plantation management but there is a need of tree improvement trials for *O. msoo* and more trials on establishment methods.

Conclusion and Recommendations

There is generally good recruitment of *Oxystigma msoo* in Rau Forest Reserve and consequently a good regeneration trend. However there is a limited recruitment from seedlings to saplings because of over exploitation of saplings for making broom handles. There was a significant difference in mean height between *O. msoo* grown in Lushoto Arboretum and Bush back valley but not in mean DBH. Being one of the most important tree species in Tanzania, it is suggested that better management practices of Rau Forest Reserve where *O. msoo* grows naturally should be adopted. Conservation strategies of *O. msoo* through community based practices in the Reserve by using villagers surrounding the reserve should be initiated. This probably will reduce illegal harvesting of saplings as villagers will be part of the management of the reserve. Encouraging villagers to grow *O. msoo* and other species in their own woodlots to substitute the use of *O. msoo* in Rau Forest Reserve is another option of conserving the species. Extension services should be started in order to enable wood users to put *O. msoo* to better and appropriate uses. Silvicultural and tree improvement research should be intensified order to increase its productivity.

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IMPACT OF JOINT FOREST MANAGEMENT ON FOREST COVER CHANGES IN MINZIRO FOREST RESERVE IN MISSENYE DISTRICT, TANZANIA

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Abstract

The objective of this study was to assess the impact of Joint Forest Management (JFM) on forest cover changes in Minziro Forest Reserve. The study was conducted in 2009 in Missenye District in Kagera Region. Two Landsat Thematic Mapper images of 1999 and 2009 for Minziro Forest Reserve were collected and analyzed to detect forest cover changes after ten years of JFM. Data analysis involved image processing and post classification change detection using ERDAS 9.2. Results indicated that the areas under different forest cover types have substantially decreased. The area under natural forest has decreased by 45% amounting to 9576 ha. Similarly there was increase in area under settlements by 67% (863 ha) in the forested area. The closed and the open woodland forest cover increased by 640% and 21% respectively. The study concluded that, JFM implementation in Minziro Forest Reserve, closed forest cover has decreased at the expense of other land uses. It has been observed that JFM has been heavily promoted with a strong conservation interest ignoring local use options. The lack of Joint Management Agreement (JMA), incentives and poor collaboration between members, were the most reported challenges to the performance of JFM in management of Minziro Forest Reserve. Among others, the study recommends for a need to rationalize and harmonize the institutional rules in JFM that guide management and revenue distribution to ensure sustainable forest management.

Keywords: *JFM, Minziro, Forest cover types, Impact, Management.*

Introduction

Past approaches in natural resource management in Tanzania have been centralized causing significant tensions between resource users and the national government, resulting in unsustainable resource extraction in the country (Kajembe, and Mgoo, 1999). To address the ineffective management of past policies, decentralization of natural resource management has been instituted, transferring power from the state to actors and institutions at lower administrative levels (Ribot, 2002).

Tanzania has followed the global trend in adopting decentralization policies in forest management. Participatory Forest Management (PFM) is a major strategy established to promote sustainable forest management and improvement of community livelihood, as stipulated in Tanzania's Forest Policy (URT 1998), Forest Act (URT 2002) and National Forest Programme (URT 2001). The Law recognizes two different types of PFM-Community Based Forest Management-CBFM and Joint Forest management JFM.

There are several arguments behind the rising natural resources related challenges. Some literatures indicate that failure of conventional scientific approaches to resource management is because they are based on faulty models, limited and socially inappropriate goals and incomplete on basic parameters Ostrom, E. (2009). That is, they do not adequately address environmental complexity, heterogeneity or the role of recurring disturbances (Finlayson and McCay, 1998). In addition, conventional scientific approaches to natural resource management often fail to create the local social institutions needed to encourage environmentally appropriate social behaviour. Eventually, institutional failure has resulted into inadequate locally derived institution needed to coordinate the compliance of resource users (*ibid*). Centrally imposed regulations for monitoring compliance, meeting out sanctions, and distributing access are clumsy, and often poorly adapted to local conditions North, D.C. (1990).

In Tanzania, Participatory forest management was introduced in 1990s to enable community involvement in management of their surrounding resource and ensure sustainable forest utilization (Kajembe, and Kessy, 2000). There several concerns that have been raised in relation to sustainability of JFM activities and on achievement of its intended objectives. Literatures indicate inadequate and inappropriate institutional frameworks in JFM strategy to ensure achievement of intended objectives URT (2006). As a result resource degradation and widespread conflicts among and between resource users have been common. These challenges differ in term of geographical settings, nature of resource involved and incentives behind community management. This study assesses the impact of JFM on Minziro forest Reserve.

Materials and Methods
Study area
Location
This study was conducted in Missenyi District in Kagera Region. Missenyi District is among the recently established Districts in the country. Its operation started in July 2007 after dividing the former Bukoba District. The District is situated on the Western side of Lake Victoria, positioned between31^{o} 30.00' East 1^{o} 5.00' South with altitude of 1,143 - 1,180m. It borders the Republic of Uganda in the North, Karagwe District in the West and Bukoba District in the South and East.

Site description
Minziro Forest Reserve is a groundwater-forest with extensive areas of grassland. Kere Hill, a small rock outcrop at 1,180 m, lies within the reserve and the village of Minziro at 1,330m sits on higher ground with the Forest Reserve extending around it, to the south and east is the Kagera River while the northern boundary is formed by the international border with Uganda. North of the border the contiguous forest is known as Malabigambo Forest Reserve, one of the Sango Bay forests. Minziro is the largest forested area in north-west Tanzania and is essentially an outlier of the Guinea-Congo lowland forests. A few kilometres to the south the vegetation changes dramatically on the higher plateau country of Kagera Region. Minziro is therefore a unique habitat-type in Tanzania. The significant tree of economic value is *Podocarpus spp*, but this has been heavily exploited and few large trees remain. A stretch of the Kagera River with stands of papyrus (*Cyperus papyrus)* is included in this site

Data collection
Remote sensing data were used to obtain information on forest cover changes as influenced by establishment of Joint Forest Management strategy. Two Landsat Thematic Mapper images of 1999 and 2009 were collected and analyzed. The 1999 satellite image was collected to determine the forest condition before the establishment of Joint Forest Management, whereas the 2009 satellite image was collected to indicate forest cover condition after ten years operation of Joint Forest Management in Minziro Forest Reserve. Upon image selection and acquisition the following processes were done, satellite imagery interpretation (processing and image classification) and change detection.

Satellite images interpretation

Image processing

This involved image pre-processing, image rectification/geo-referencing and image enhancement. The images were geo-referenced to the real world coordinate system. Enhancement usually reinforces the visual interpretation of the images. False colours composites were created by combining images captured at different wavelengths to enable better visualization of vegetation, water bodies and settlement in the area Kashaigili, 2006.

Image classification

Both visual and digital image classification approaches were used. The contrast stretch, spatial filtering, and colour composite image enhancement techniques were used for visual image interpretation Kashaigili, 2006. Through visual interpretation, features showing changes in forest cover were extracted. Supervised image classification using maximum likelihood classifier was performed using ERDAS 9.2 imagery software. Training fields were identified by inspecting enhanced colour composite bands 4, 5 and 3 ERDAS (1999).

Change detection analysis

Change detection analysis was done by quantify temporal effects using multi temporal data sets Post-classification change detection approach was applied were two imageries from different dates(1999 and 2009) were classified and labelled and the area of change extracted through the direct comparison of the classification results (Mbilinyi, 2000, Kashaigili *et al.*, 2006). The imageries of 1999 and 2009 were analyzed and the detection of forest cover was carried out.

Assessment of the rate of Forest covers change

The estimation for the rate of change for the different covers was computed based on the formulae developed by (Kashaigili, 2006);

$$\%\ Cover\ change = \frac{Cover\ area_t - Cover\ area_{t+1}}{Cover\ area_t}\ x\ 100\% \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{i}$$

$$Annual\ rate\ of\ area\ change = \frac{Cover\ area_t - Cover\ area_{t+1}}{t_{years}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{ii}$$

$$\%\ Annual rate of\ area change = \frac{Cover\ area_t - Cover\ area_{t+1}}{Cover\ area_t * t_{years}}\ x\ 100\% \ldots\ldots\ldots\ldots\ldots\ldots .iii$$

Where:

Cover area$_t$ = area of cover at the first date,

Cover area$_{t+1}$ = area of cover at the second date, and

t_{years} = the difference in years between the first and second scene acquisition dates.

Data analysis

Satellite images were analyzed by ERDAS 9.2 Software ERDAS (1999). After appropriate descriptive and analytical procedures results was presented in relevant table format, and graphical techniques such as table, and pie charts to enable for easy inferences and interpretation of the information.

Results and Discussion

Forest cover change

Assessment of changes in forest cover types in the study area have been categorized into seven groups these includes Natural forest, closed woodland, open woodland, grassland, cultivated land, settlement and catchment area. Findings from the study area indicate Minziro forest reserve has experienced serious degradation which threatens the sustainability of the forest. This is evident from the analysis of satellite images of 1999 and 2009.To facilitate the discussion a summary of the overall trend in forest cover changes is presented followed by detailed analysis of forest cover change types in 1999 and 2009 images. Assessment of forest cover change between 1999 and 2009 (table 1) has shown that area under different forest cover types have substantially decreased with little improvements observed on catchment forest cover.

Table 1: Forest cover changes from 1999 to 2009

Minziro Forest Cover Change 1999-2009					
	Coverage in Ha		Cover change		Annual rate of change
	1999	2009	2009	2009	
Forest Cover changes	Ha	Ha	Ha	%	Ha
Closed Woodland	1127	8336	+7209	+640	+720.9
Open Woodland	7729	9356	+1627	+21	+162.7
Natural/Primary Forest	21132	11556	-9576	-45	-957.6
Cultivated Land	34690	30235	-4455	-13	-445.5
Bushed Grassland	23523	27827	+4304	+18	+430.4
Catchment area/water	137	165	+28	+20	+2.8
Settlement	1283	2146	+863	+65	+86.3
Total	89621	89621			

(- =Decrease, + =Increase)

Change in natural/primary forest cover, settlement and cultivation area

The analysis of forest cover change in Minziro Forest Reserve has shown that there has been severe degradation of forest and conversion of forest land into different land use types like cultivation and settlement area. Such processes have led to different forest cover types to decrease while only limited forest cover type have increased. Figure 1 below indicate nature of the various forest cover types as indicated in 1999 satellite image.

The findings shows that within the period of ten years between 1999 and 2009, the area under natural forest has decreased by 45% amounting to 9,576 ha; similarly the area under settlement has substantially increased by 67%.which is about 863 ha. The findings indicate there is more demand for settlement areas. However, contrary to expectation land under cultivation has decreased by 13%. This may raise two suggestions, firstly although there was more demand for land for settlement, such people could be involved in other non-farm activities such as petty business and fishing than crop cultivation, secondly the observed forest degradation in the study area could be a result of other factors apart from the demand for cultivation area.

Furthermore the reported changes in natural/primary forest cover from 21,132 ha in 1999 to 11,556 ha in 2009 (Figure 2) and reported increase in its subsequent forest cover (closed woodland), were there is a reported increase of 720 ha in 2009, perfectly fits the puzzle, where the decreased 957 ha in the primary/natural forest could be linked to the increased 720 ha in the closed woodland forest cover. However in relation to the existence and operation of JFM committee in forest management at village level, the reported decrease of 45% in natural/primary forest cover and substantial increase of settlement in the forested land by 67% indicate weak enforcement of JFM rules creating loop hole for continuation of forest degrading activities.

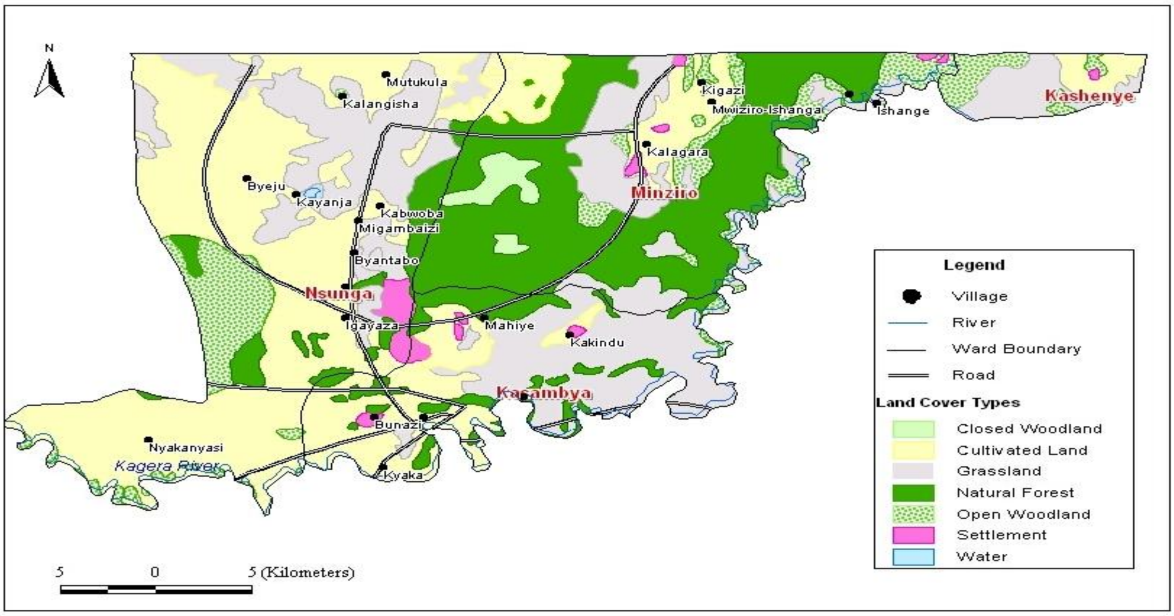

Figure 1: Land covers types in 1999

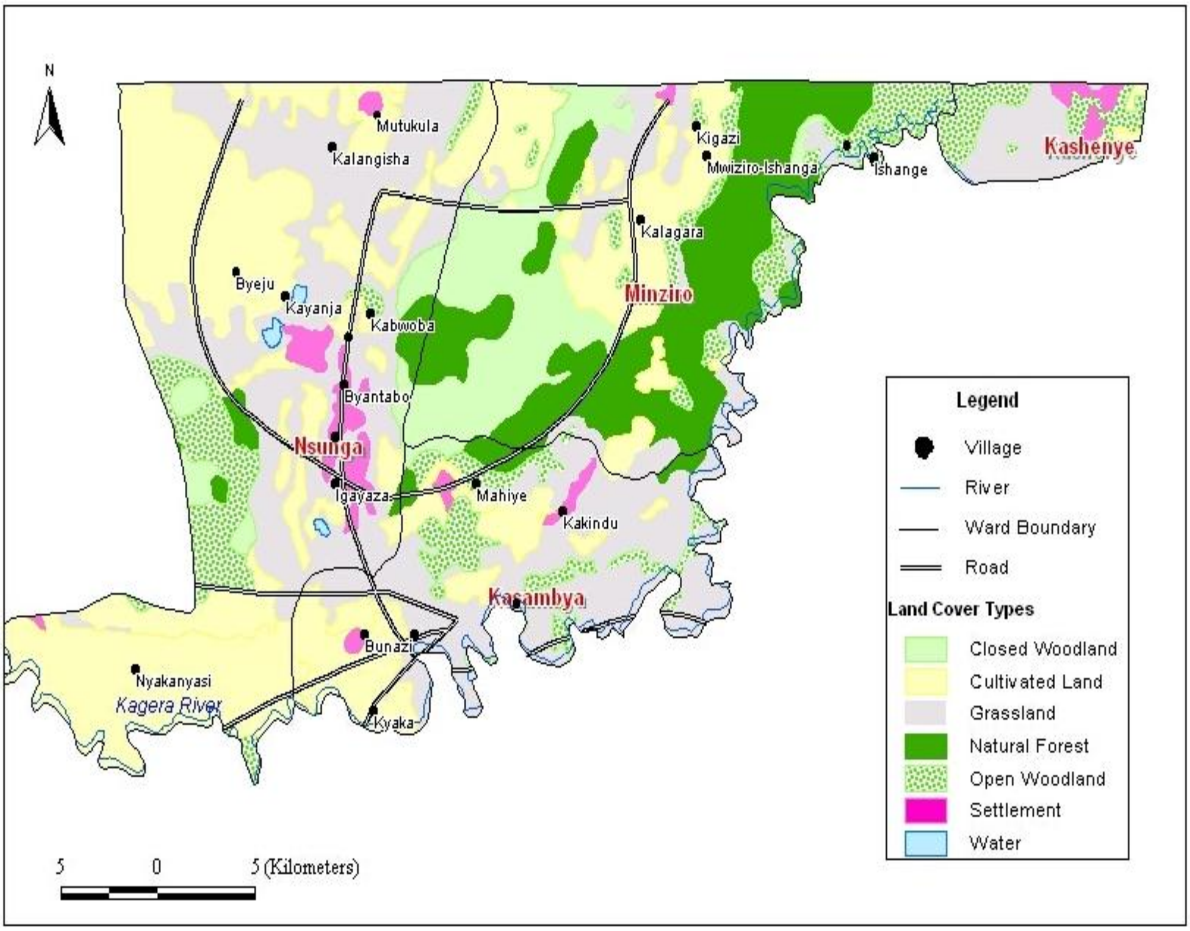

Figure 2: Land cover types in 2009.

Change of woodland forest cover

To facility interpretation, two categories of woodland forest types have been established, these are open and closed woodland. Findings for the period of ten years between 1999 and 2009 satellite imageries indicate continuous forest deterioration. In support to the previous result were we observed decrease in natural forest cover, we expected to see an increase in closed woodland cover. The findings derived from analysis of satellite images of 1999 and 2009 (Figure 2) indicate increase of closed woodland forest cover by 640%, amounting to about 7,209 ha. Additionally results for open woodland indicate a continuous increase in area under open woodland by 21% which amount to 1,627 ha. These results supports the previous findings were the natural forest cover have been reported to decrease, sequentially the decrease in natural/primary forest cover we expected increase in area of the subsequent forest cover types. These is an indication of forest deterioration were the forest indicate to have more of rejuvenile trees with less mature and merchantable class. Unless measures are taken to ensure collaboration between JFM committee, forest department and the local community members on ground in forest management, the forest status will continue to change from open woodland to bushed grassland, grassland to bare land.

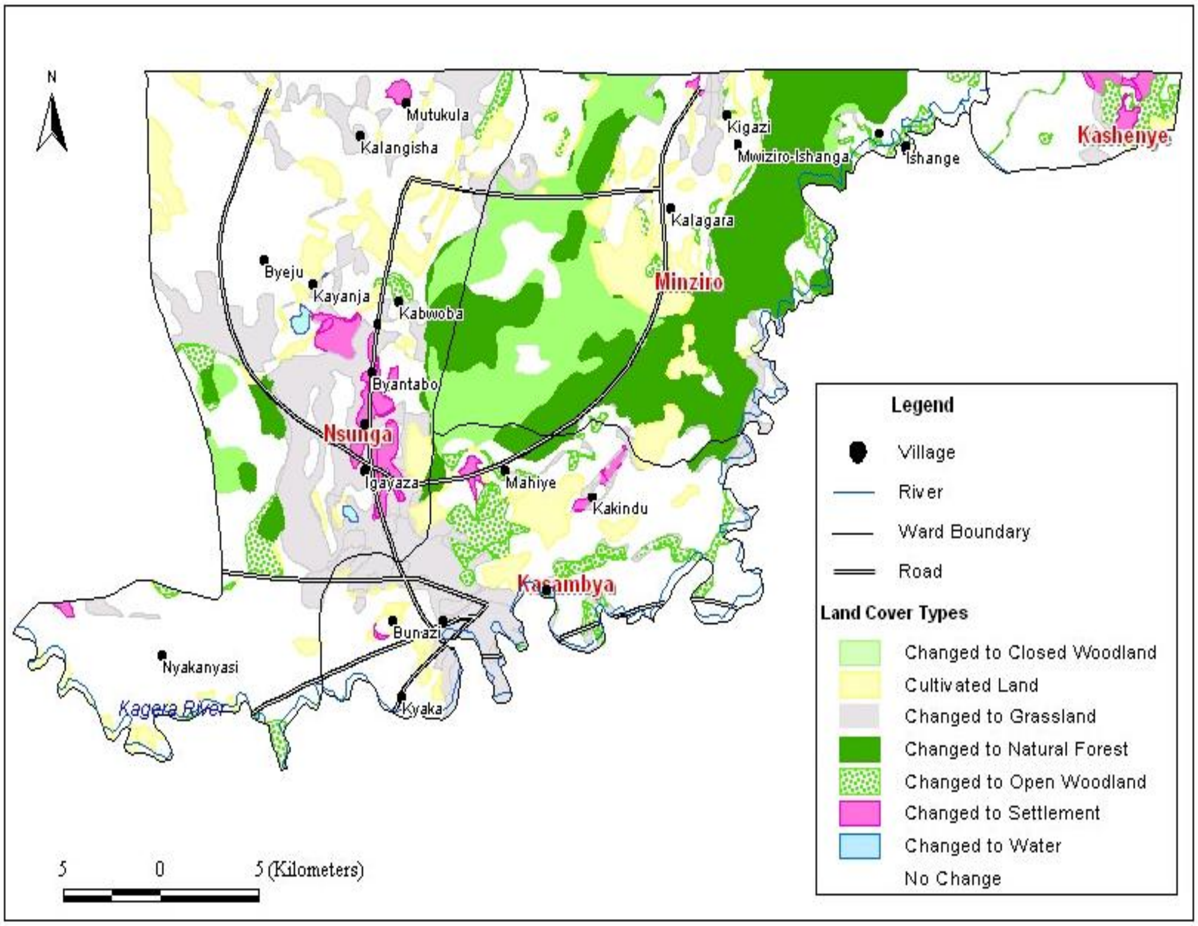

Figure 3: Spatial changes of Land cover types in 2009

Changes on Bushed grassland cover

As expected from the previous trend of cover change, observed increase in closed woodland, open woodland cover and the ultimate decrease in natural forest cover and cultivated area, these changes can directly result to an increase of area under bushed grassland. Findings derived from interpretation of satellite images of 1999 and 2009 indicate an increase of bushed grassland area by 4,304ha in 2009,(figure 3) in 1999 the satellite image indicated an area under bushed grassland to be 23,523 ha whereas in 2009 the area under bushed grassland has increased to 27,827ha. The impact of JFM strategy on management of Minziro Forest reserve is hardly noticed with these reported deterioration of forest condition.

Changes on Catchment area

Contrary to what have been observed (table 1 and figure 3) in all of the previous forest cover types, where substantial decrease in various forest cover have been reported, findings indicate increase in catchment area by 28ha as from 1999 to 2009. In relation to JFM roles in forest management the observed increase in catchment area in the study area can hardly be associated with improvement in forest management because of the sequential forest deterioration reported in different forest cover types, but Luther the improvement reported in catchment area could be a result of a time at which the satellite images were taken in (rain season). The other reasons that could result into increase in catchment area despite of substantial degradation in forest are, there various management and conservation efforts done in Lake Victoria basin (like a control of human related activities) and along river Kagera profile all the way from Burundi, Rwanda, Ngara and Karagwe before it reaches Missenyi district, thus the increase in water surface area is associated to conservation efforts done in Lake basin and not from forest management activities. In order to achieve Joint Forest Management objective there is need to ensure collaborative efforts between partner (working at community level) in resource management than working as isolated bodies, as the approach is cost effective in terms of resource invested in management, human resource involved and time factor.

Conclusion and Recommendations

Observation made during field work is that JFM has failed to supervise management of Minziro Forest Reserve. JFM in this forest is being heavily promoted with a strong conservation interest and has largely taken place in protection forests where local use options are extremely limited. The most reported challenge to the performance of JFM in management of Minziro Forest reserve is the lack of Joint Management Agreement (JMA). JMA is legal document contracted between government agency and the local community in management of forest resource.JMA clearly stipulate the role and responsibilities of both actors involved in the agreement, it also indicate the penalties to be taken to various offences.

Partnerships in JFM must grow out of a mutual sense of commitment, adequate coordination, communication, and consultation. It is important to have clarification about each other's role, goals, purpose, operation, style, and limitations. The process of clarification should take place through equitable dialogue and partnerships. Thus, an appropriate operational structure and agreement should always be developed based on the needs of Joint management arrangement so that coordination between partners will be effective without being too costly to the structure. Field experience indicate no Joint management arrangement can survive unless a relationship of trust and mutual respect is developed and maintained between the partners.

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PRODUCTIVITY OF SECOND AND SUBSEQUENT ROTATIONS: CAUSES OF DECLINE, AND MEASURES TO MAINTAIN LONG TERM FOREST SITE PRODUCTIVITY IN THE TROPICS: A REVIEW

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Abstract

Plantation forests are renewable natural resources primarily growing wood for range of purposes such as restoration of degraded soils, climate regulation, water protection, and biodiversity protection. Decline of site productivity in the successive rotations (second and third) has been noted in tropical countries. This review paper gives an overview on: productivity of second and other rotations, causes of decline and measures to maintain long term forest site productivity. Forest productivity generally refers to the amount of harvestable wood obtained from a forested site. Factors contributing to decline in site productivity include; changes in physical and chemical properties of soils, nutrient removal from soil, weed spectrum and intensity, pests and diseases as well as improper site and species selection. However, maintaining or increasing plantation productivity can be achieved by undertaking appropriate measures some of which are, forest fertilization, mixed planting, good forestry practice and weeding. Generally, it is possible to maintain or to increase forest site productivity in the second and other plantation rotations if appropriate measures are undertaken. Use of quality seedling established from registered seed sources/orchard, undertaking appropriate site preparation, avoiding planting the same species in the same piece of land for successive rotation or adapt mixed planting, timely weeding, forest fertilization and carrying out more research for improving site productivity if the species planted are newly introduced constitute such needs.

***Keywords**: Site Productivity, Plantation, Rotations, Nutrient removal, Good forestry practice.*

Introduction

Plantation forests are renewable natural resources primarily growing wood for range of purposes (Nambiar, 2006). The established plantation forests serve as a safety net after noting that, natural forests will normally not be able to sustain increasing domestic and international demands for wood and wood products. This is due to the fact that a sizable proportional of indigenous trees are slow growing and are difficult to propagate (Chamshama and Nwonwu, 2004). Plantation forests are increasing at an annual rate of about 2.5 million ha largely in subtropical environments in Asia and South America and to much less extent in Africa (Nambiar, 2006). Plantations not only offer opportunities for meeting wood demands and reducing deforestation by decreasing pressures on natural forests, but also can restore degraded soils (Tiarks, 1998). Moreover, Chamshama and Nwonwu, (2004) noted that, planted forests serve numerous ecological stabilization and protective roles such as climate regulation, soil and water protection and biodiversity protection. The great majority of planted area in tropics is based on exotic species chosen for their capacity to grow rapidly and produce wood of appropriate quality (Tiarks, 1998). This is due to the fact that, the majority of successful plantations in the tropics consists of exotics (Chamshama, 2001). Exotics are fast growing and has high productivity compared to indigenous tree species. Examples of Exotic species mostly grown include Eucalyptus spp, Tectona spp, Acacia spp, Pinus spp and other conifers. Productivity of plantations needs to be high and sustainable because of the large initial investments required (Tiarks, 1998).

Productivity usually means harvestable wood that can be obtained per year on a forested site (Libby, 2002). It also involves the quality of the harvested wood for various purposes, and it includes other goods and services that can be offered (FAO, 2002). Site productivity is the determining factor in the rate of return from forest investment (Dupuy and Mille, 1993). In some instances new areas are being opened up for plantations in order to increase forest products, this is due to the fact that, most parts of the tropics, the first rotation crops have shown high growth rates and thus high productivity. However, according to Chamshama, (2001) future wood needs will have to be obtained from existing planting areas. Therefore there is a need for maintaining long-time site productivity. This review paper gives an overview on; productivity of second and other plantation rotations, causes of decline in forest site productivity and measures to maintain long term forest site productivity, as the understanding of these attributes is critical for the sustainability of plantation forest in tropical countries. Normally one rotation for trees in plantations takes about 25 years and most of the plantations were planted in 1950s in Tanzania hence they enter into third rotation.

Productivity of Second and Other Rotations

Productivity of plantations needs to be high and sustainable because of the large investments requirements and they must be economically viable (Tiarks *et al*., 1998). However, productivity declines over successive rotations of tree (Evans, 2008). Earlier information on decline of forest productivity was obtained in Australia. Significant yield decline in second rotation *Pinus radiata* appeared in South Australia in the early 1960s, with an average 30 per cent drop. However, elsewhere in Australia second rotation crops are mostly equal or superior to first rotation (Evans, 1999 In Evans, 2008). This inspired research on monitoring of productivity in the subsequent rotations in other areas where plantations have been established.

According to Evans, (2008) long-term productivity research in the Usutu forest, Swaziland began in 1968 as a direct consequence of second rotation decline reports from South Australia. For 32 years measurements have been made over three successive rotations of *Pinus patula* plantations, grown for pulpwood. Over most of the forest where granite derived soils occur, third rotation height growth is significantly superior to second (Table 1). There had been little difference between first and second rotation (Evans 1978 in Evans, 2008).

Table 1: Comparison of second and third rotation *Pinus patula* on granite and gneiss derived soils at 13/14 years of age (means of 38 plots) in Usutu Forest, Swaziland.

Rotation	stocking (stems ha^{-1})	Mean height (m)	Mean DBH (cm)	Mean tree vol. (m^3)	Stand vol. (m^3ha^{-1})
Second	1386	17.5	20.1	0.205	294
Third	1248	18.7	21.2	0.233	326
% change		+6.9	+5.5		+11.0

Source: (Evans, 2008)

Table 2: Comparison of second and third rotation *Pinus patula* on gabbro dominated soils at 13/14 years of age (means of 11 plots) Usutu Forest, Swaziland

Rotation	Stocking (stems ha^{-1})	Mean height (m)	Mean DBH (cm)	Mean tree vol. (m^3)	Stand vol. (m^3ha^{-1})
Second	1213	16.7	20.0	0.206	244
Third	1097	16.8	21.7	0.227	255
%change		+0.5	+8.5		+4.5

Source: (Evans, 2008)

On a small part of the forest (about 13% of area), on phosphate-poor soils derived from slow-weathering gabbro, a decline had occurred between first and second rotation, but this had not continued into the third rotation where there is no significant differences between rotations (Table 2). This is an indication that productivity in the plantation forest decline but also it can be maintained or improved if appropriate measures to maintain long-term forest productivity are undertaken. In Tanzania not yet done but there is need of carrying out soil analysis in all tree plantation after the second rotation.

Causes of Decline in Forest Site Productivity

Changes in soil properties

Soil properties such as physical (structure and texture) and chemical (pH and nutrients content) are important for plant growth. Changes or destruction of soil properties can result into decline in soil fertility and hence poor plant productivity. According to Goncalves *et al.* (2006) soil fertility decline is caused by management that does not conserve soil and site resources and damage soil physical and chemical characteristics. For example harvesting and log transportation by use of machinery can not only cause soil compaction but also loosening of upper layer of the soil surface and hence exposing the soil to the agents of soil erosion (e.g. surface run-off) which contributes to changes in soil properties. The mechanical harvesting also lead to top soil compaction which reduces air spaces in the soil this reduce air storage for plant roots, and for microorganism respiration (Maliondo and Chamshama, 1996). In Tanzania especially Sao Hill normally harvesting is done through semi mechanical and manually for small holder operators (Balama *et al.*, 2005).

Nutrient removal from soil

Removal due to tree harvesting

According to Lundgren, (1978) *Pinus patula* plantations in Tanzania led to annual removals of 40 (N), 4 (P), 23(K), 25 (Ca) and 6 (Mg) kg ha^{-1}. These rates of removal are about one-third of those of maize (Sanchez, 1976). Continuing planting tree in the same land will result into more nutrients removal and hence lower yield or total plantation failure. In northern Tanzania all product from trees are removed from the plantation hence more prone to loss of fertility with time (Bakari *et al*., 2006). The nutrient deficiency in soil can be revealed by absence of one among sixteen essential elements, which are considered important in plant growth, and in metabolism. Three elements including carbon, hydrogen and oxygen, are readily available from the air and water, while the remaining thirteen elements are obtained from the soil complex (Clatterbuck, 2007). In plantation forests a large portion of nutrients are removed after every rotation due to removal of large proportional of above ground biomass. The amount and rates at which nutrients are removed from site in biomass depends on the species grown, the degree to which biomass is utilized and the rotation age of the crop (Chamshama, 2001). Degree of utilization of biomass can increase the amount of specific nutrients removed from the forest (Table 3)

Table 3: The effect of degree of utilization of biomass from *Pinus radiata* plantation harvestable at age 29 years on nutrient removal location in Australia

	Stem wood and bark	Full tree	Defoliated full tree
Biomass harvest Kg ha^{-1}	361	426	418
Nutrient removal Kg ha^{-1}			
N kg ha^{-1}	214	439	318
P kg ha^{-1}	31	66	66

Source: Raison *et al.* (1982) In Chamshama, (2001)

Nutrient loss due to litter and residues removal or burning

The influence of litter on soil chemical status may be important since leaves of different species decay at different rates (Evans, 2008). Removal of litter and residue before decay can interrupt nutrient cycling in the production sites and hence result into nutrient loss and decline site productivity. Dupuy and Mille, (1993) noted that burning of litter and logging residue results in substantial losses of nutrients, for example nitrogen in gaseous forms. Furthermore, Maliondo and Chamshama, (1996) added that, a further loss of nutrients is caused by leaching of mineralized nutrients which is caused by soil exposure following removal or burning of litter and logging.

Pests and diseases

It is generally believed that outstanding initial performance of exotic species in the areas of introduction is attributed to the absence of pests or diseases (Chamshama and Nshubemuki, 1998). However, with time, diseases and or pests tend to be active and then cause threat to plantation forests. Maliondo and Chamshama, (1996) noted that emergence of new pests and pathogens introduced or indigenous ones, which were not active during first rotation (*Cinara cuppressivora)* are now affecting most of the *Cuppress lustanica* stands in E. Africa. These, infestation a decade ago of *Cuppress lustanica* by *Cinara cupressivora* have threatened future planting programmes of the tree species (FAO, 1991). The status of forest insect pest in Tanzania was investigated and found most exotic species are still attacked by insects with variable intensity. The cypress aphid, Leucaena psyllid, pine woolly aphid and blue gum chalicid are the main forest plantation insect pests (Madoffe and Petro, 2011).

Climate change

Climatic condition such as temperature and rainfall are important for plant growth. According to FAO, (2003) changes in rainfall pattern and change in seasonality can directly affects the growth of tree species and soil properties, resulting into reduction in productivity among different rotations. Studies in Usutu forest, Swaziland have shown significantly reduced growth of second rotation of *Pinus patula* due to successive of very dry and prolonged winters in the mid 1970’s (Evans, 1978 In Chamshama, 2001).

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Measures to Maintain Long Term Forest Site Productivity

The productivity of the second and other rotations will have to be maintained or increased to meet the increasing domestic and international demands for wood and wood products. Maintaining or increasing plantation productivity can be achieved by undertaking the measures such as forest fertilization, mixed planting, good forest practice and weeding.

Forest fertilization

Forest fertilizations is gaining prominence with the extension of plantations into more marginal sites and the need to enhance tree growth and maintain productivity of second and subsequent rotations. According to Chamshama, (2001) fertilizers have been applied in the forest plantations to amend nutrient deficiencies for early stage in increasing survival and growth of seedlings. The report from the study conducted in China on the effect of fertilization shows that, fertilization increased tree height and diameter growth on planted tree for the first ninety (90) months of observation. It is suggested that the level of fertilization in plantation in degraded land should be high enough to achieve reasonable productivity (Xu *et al.*, 2006).

Mixed planting

Mixed forest plantation is a type of forest where by more than one tree species is deliberately planted together in a given area. This type of forest plantation is good for nutrient circulation as well as pests and disease control compared to monoculture plantation. According to Laclau *et al.* (2006) mixed plantations with Nitrogen-fixing species might be an attractive option to improve the long-term soil N status. In soils that are inherently infertile, or on better soil that have been depleted of nutrients in some forest stands, productivity is limited due to low total nitrogen levels. In these situations, use of nitrogen fixing tree species like legumes such as *Acacia*, *Leucaena* and *Albizia* which are symbiotically associated with Rhizobium species, increases nitrogen availability in a mixtures stand (Domingo, 1983), hence increase tree growth (Fig 3). For some extent mixed cropping is better than forest fertilization approach since it is cheaper, environmental friendly and tends to give high productivity. Debell, (1985) noted Height and diameter of *Eucalyptus* trees in the mixed plantings were greater than in the pure plantings even though the latter received additional N fertilizer.

Good forestry practice

The success of any plantation depends largely on adoption of appropriate silvicultural practices, which consist of various treatments applied to forest plantations to maintain their long-term productivity in the second and other plantation rotation.

Some of these practices include: choice of species including seed source, genetic improvement, mulching, site preparation, and harvesting practices (FAO, 2001a; FAO 2001b). Appropriate and timely silvicultural practices also called good forestry practice since determine the pattern and quality of crop development thereby modifying both the quality and the quantity of end products (Evans, 2008).

a) Seed source and planting stock

Seed origin or seed quality of the same species may have influence in productivity. Poor genetic quality, poor quality seeds results into reduced productivity of the second and other plantation rotations (Evans, 2008). Therefore for sustainability of productivity of forest plantations, genetically superior seed and high quality planting seeds stock should be used for plantation establishment.

b) Mulching

In forest plantation slash, litter should be left in plantation site, so that can act as mulching materials. Mulching helps in conservation soil against agent of soil erosion and adds soil nutrients after its decomposition and on improvement of stand productivity Mugasha *et al.* (2003) notified that, slash should be retained on site after harvesting. According to Deleporte *et al.,* (2006) noted that the amount of organic matter left at the soil surface after harvest of the previous stand have significant effect on the tree growth throughout the next plantation rotation.

c) Site preparation and harvesting practices

Before re-establishment of plantation forest for the second and or any other rotations, site preparation is important. According to FAO, (2001a) proper site preparation prior to establishment and re-establishment of plantation aims at minimizing negative impact due to compaction, loss of organic matter, soil erosion and nutrients deficit. Rigorous site preparation (deep ploughing and harrowing) have resulted into improved survival and early growth of planted seedlings, attained by reducing weed competition and increased water infiltration and storage as well as reducing surface runoff (Maliondo and Chamshama, 1996). Therefore use of conservative site preparation may improve long term site productivity. On other hand, proper planning for harvesting is vital for sustainability of productivity in the second and other rotations. According to FAO, (2001c) proper harvesting planning which among others includes careful re-use of extraction routes to minimize compaction and erosion. Both soil compaction and erosion affect soil fertility, hence contributing to less plantation yields in subsequent forest plantation rotations

d) Weeding

Weeding of planted seedlings is necessary in order to reduce or eliminate competition for light, soil moisture and nutrients from undesirable species. Weeding is usually done manually using hand tools. The types of weeding used in Tanzania include clean weeding (in some places using the taungya system, strip weeding, spot weeding, slashing and climber cutting (Isango and Nshubemuki, 1998). Despite the superiority of clean weeding (manual or chemical) on survival and growth, spot and strip weedings are often used depending on the site, species and financial availability (Abeli and Maliondo, 1992 in Chamshama, 2001).

Conclusion and Recommendations

Conclusion

Sustainability of productivity second and other plantation rotation is important for maintaining constant supply of industry raw materials, non-timber forest products and providing other ecosystem services like carbon sequestration and hence mitigation of climate change. Decline in forest site productivity is caused by various factors including; changes in soil properties, nutrient removal, pest and disease, climate change and many others. Forest fertilization, good forestry practice and weeding are some of the important measures to be taken against decline in site productivity in second and other plantation rotations**.** Therefore, it is possible to maintain or increase site productivity in the second and other rotations if appropriate measures to improve site productivity will be taken into considerations.

Recommendations

In order to maintain long term forest productivity in Tanzania, the following are recommended: use of quality seedling established from registered seed sources/orchard; undertake appropriate site preparation; avoiding planting the same species in the same piece of land for successive rotation or adapt mixed planting. Weeding at early stage in plantation to reduce the competition for light, soil moisture and nutrient from undesirable species. There is need of carrying out more research for improving site productivity if the species planted are newly introduced.

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