Addis Ababa University
School of Graduate Studies
Department of Biology

The conservation status of *Pterocarpus angolensis* D.C in Nguru ya Ndege Forest Reserve, Morogoro-Tanzania

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M.Sc. thesis submitted to the school of graduate studies, Addis Ababa University in the partial fulfilment of the requirements of the Degree - Dryland Biodiversity

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By

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A Thesis Presented to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in dryland Biodiversity

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DEDICATION

To my Mother Pelagia Byamungu and my Father Modest Byamungu who through their love and care brought me up.

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ABREVIATIONS AND ACRONYMS

AAU	Addis Ababa University
DBH	Diameter at Breast Height
FGR	Forest Genetic Resources
IUCN	International Union for Conservation of Nature and Natural Resources
IVI	Important Value index
a.s.l	above sea level
ODI	Oversees Development Institute
RPSUD	Research Program on Sustainable Use of Dryland Biodiversity
WCMC	World Conservation Monitoring centre
NTSP	National tree seed programme in Tanzania
ITTO	International Tropical Timber Organization
USDA	United States Department of Agriculture
WAC	World Agroforestry Centre
ICRAF	International Center for Research in Agroforestry
SADC	Southern African Development Community
OSSREA	Organization for Social Science Research in Eastern and Southern Africa
CIRAN	Centre for International Research and Advisory Networks
SSC	Species Survival Commission
NAPRECA	Natural Products Research Network for Eastern and Central Africa
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
AETFAT	Association for the taxonomic study of the flora of tropical Africa
SARCCUS	Southern African Regional Commission for the Conservation and Utilization of the Soil
LR (nt)	Lower Risk (near threatened)

ABSTRACT

A study was carried out in Nguru ya Ndege Forest Reserve, Morogoro- Tanzania. Simple random sampling method was applied in sampling of the vegetations. Objectives of this study were to determine the spatial distribution and population structure of ***P. angolensis*** in Nguru ya Ndege Forest Reserve, and to assess the density and the extent of exploitation of ***P. angolensis*** in Nguru ya Ndege Forest Reserve. A total of 102 woody species were recorded during the study falling in 71 genera and 30 families. The results showed that; the population density of ***P. angolensis*** in Nguru ya Ndege Forest Reserve was 19 stems/ha for individuals with DBH $\geq$ 4 cm. The plot of DBH class distribution showed a characteristic inverted J shape for ***P. angolensis***, although the trend seemed interrupted. From the generated ArcView map it was observed that the distribution of ***P. angolensis*** in Nguru ya Ndege Forest Reserve was not even as quadrats into which the species was recorded seemed concentrated more in the higher altitudes of the reserve than lower plains. It was also found that, mature individuals of ***P. angolensis*** in Nguru ya Ndege Forest Reserve are being selectively removed for timber sawing. This study concluded that, the store of ***P. angolensis*** in Nguru ya Ndege Forest Reserve is still promising, and its population structure might show a normal trend in future if the forest is put in a well-managed regime. This study recommended among others, to transplant seedlings of ***P. angolensis*** especially in the northern, western and southern parts in order to restore those denuded areas of the reserve.

1 INTRODUCTION

1.1 General introduction

1.1.1 Background information

The knowledge of the natural forest environments, basically means knowing the status of each unit comprising that forest; natural forests environment are made up of vegetations, animal and humans who draw their living from the forest soils, minerals and streams (Desta Hamito, 2001). It is clearly known that forests in the tropics are extremely rich in plants and animal species but majority of these species have yet been scientifically described and very little is known about their ecology (Blockhus *et al.,* 1992). Forests in the tropics are not static ecosystems enough to maintain a fixed climax species composition over a long period of time; they have been subjected to modification by climatical, geo-morphological and human influences through their evolutionary history. Such habitat changes caused by activities such as tree felling including selective removal of timber trees usually result in long lasting disturbances (Blockhus *et al.,* 1992). The more intensive the forest is used, the more the structural and composition are altered from the original state (Poore and Sayer, 1991).

In general, the threatened status of tree species results from processes of habitat modification and destruction. Specific threats may also result from direct exploitation of the species for timber or other products at rates which are unsustainable. The threats mostly documented are; Felling, Agriculture, Expansion of settlement, Grazing, Burning, Invasive plants, Forest management, Local use, Mining/exploitation, Tourism/leisure, (WCMC, 2000; Schreckenberg, 2000). The reasons centring those threats are various; for example, a central reason for the population of Doguè in Ivory Coast to light fires around settlements, but also in savannas and woodlands, is the achievement of higher visibility. Visibility reduces a general fear and in fact the risk of attacks by wild animals. Hunters are interested in a higher visibility in order to find their prey, and they also use fires as a hunting method. Herdsmen set fires to initiate an off-season re-growth of perennial herbs as well as to get rid of the unpalatable stubbles (Menaut and César, 1991).

With the objective of sustainable use of forest resources now being included in a number of national and international policy initiatives, attention is focusing on how the sustainability of forest management activities may be assessed in practice. To assess the relationship between sustainable use and conservation of tree species three different aspects are considered separately: the potential for sustainable use- based upon the biological characteristics of a species; the intrinsic likelihood of a particular use being sustainable - based upon the part of the plant harvested; and the impact of use on the conservation status of a species (Sharma, 1992). For example, harvesting of timber from a natural forest has profound effects on biodiversity of the forest ecosystem as that harvesting reduces the forest's diversity and structural variation (Heywood and Watson, 1995), and selective harvesting contributes significantly to loss of individual tree species (Tisdell, 1991; Shepherd, 1992). Disappearance of an individual tree species is coupled with negative implication to the ecosystem in general as other organisms depending on such a tree may face setbacks as a consequence of loss of their host (Johns, 1992).

Harvesting forests for timber is not a sole way of forests exploitation in tropics, other uses exists such as; Firewood collection, Charcoal burning, Building materials, Domestic items (e.g. Mortar, pestle, spoon, axe handle, bow, arrow handle, spear handle), Fodder, Beverages/Food/Condiments, Fruits, Fencing materials, Gums/Tannins/Resins, Crafts, Honey collection, Ritual/Spiritual services, Dye extraction, Fibre and Medicine (Hines and Eckman , 1993), for example, a small scale charcoal production is a significant source of income for many small farmers, predominantly men, as well as a significant cause of deforestation, notably the Miombo woodlands. It is estimated that over 40 million people inhabit areas of the miombo woodland in central, southern and eastern Africa, with an additional of 15 million urban dwellers relying on miombo resources such as wood or charcoal (Campbell *et al.,* 1996). For example, in most rural areas of Tanzania forests are still the main sources of supply for materials used in constructing houses and fences. Even though house construction styles are slightly different in various regions of the country, the majority of rural people still rely on local forests for their house construction needs. The high demand for building materials puts considerable pressure on natural forests, especially those near villages and towns (Hines and Eckman, 1993). Experiences from Kenya indicate that, the most commonly used tree species for woodcarvings are depleted close to extinction and can only be found in areas distant from markets selling craft products (Obunga, 1995). The most affected tree species from woodcarvings activities include *Brachylaena huillensis, Dalbergia melanoxylon, Olea europaea, Spirostachys africana* and *Combretum schumannii* (Choge, 2002). Depletion of intraspecific genetic variation ('genetic erosion') is therefore likely to occur as a result of deforestation, as genetically distinctive populations and individuals are lost (Ledig, 1992).

1.1.2 Species conservation status

The conservation status of a species is an indicator of the likelihood of that species continuing to survive either in the present day or the future. Many factors are taken into account when assessing the conservation status of a species including: the number remaining, overall increase or decrease in population over time, breeding success rates, known threats, among others (Wikipedia, 2006). The conservation of biodiversity and its sustainable management are internationally recognized as vital global concerns. Identification of the components of biodiversity and the threats they face are important steps in planning for conservation action. Tree species are ecologically, culturally and economically valuable components of biodiversity and their conservation is essential to the well being of people in all countries of the world. With increasing general pressures on ecosystems and selective pressures on species, it has become apparent that many tree species are threatened with extinction. Information on the degree and extent of threat has, however, previously been scattered and scarce. Thus, assessment of the conservation status of the world’s tree species is a major task given the overall number of trees believed to exist (WCMC, 2000).

Assessments of forests at the scale of a nation, or even at the scale of a management unit are inappropriate for assessing the impact of use on individual species. Thus, the sustainability of a forest does not provide an adequate framework for assessing the conservation status of individual tree species. For example, management of a forest as a whole may be achieving a sustainable yield in terms of total timber volume but the most valuable timber species in the same forest type might be suffering over cut. Alternative approaches need to be developed rather than general forest management; therefore, the uses on individual species provide a more appropriate focus (ITTO, 1990). Species differ in their biological characteristics which determine their ability to withstand use, and these same characteristics enable the species to tolerate or to recover after harvesting. The key characteristics, therefore, are those which determine the regeneration capacity of the species, including reproductive biology - natural regeneration of a species may be irregular, leading to populations with few young individuals, or a high proportion of individuals within a narrow range of age classes. Such species will be much less able to maintain population size if individuals are removed by harvesting. The same applies to species which occur at low density, particularly with uneven distributions (Peters, 1994). Researches are urgently needed on the population biology and autecology of globally threatened tree species. For practical application, research and information exchange are also needed on aspects of sustainability relating to tree species utilization, particularly for those species categorized as Vulnerable. Nevertheless, the potential for tree species loss is a universal problem and needs to be tackled in all countries and at all levels; Local people may not always appreciate that a species they harvest has a narrow geographic distribution and is wholly dependent on local wise use for its conservation (WCMC, 2000).

Tuxill and Nabhan, (2001) argues that, for a specific identification as a protection priority it is desirable to have baseline information on abundance, density, size and reproduction status of a concerned plant species. This idea is also observed by Cunningham, (2001) that, classification of tree plants in class-sizes based on stem diameters showing size-class distribution are ways of showing plant population structure indicating the chance of plants in one size class to survive into next size class. This classification is used for understanding plant population dynamics mostly for trees, and give indication of size-specific mortality and therefore the status of the population. Martin, (1995) also stresses the same point, that, if one chooses to focus on a specific plant resource for study, he/she may want to measure the number of individuals found in different size classes as a first step towards understanding the population dynamics of the species. Harper, (1994) also asserts that, the size structure of the tree species is some measure of its future and is useful to a forester who needs to make predictions about its fate. Measures to secure the declining status of a tree species includes (WCMC, 2000); research into the reasons for decline, protective legislation, *in situ* protection within designated conservation areas, management of populations in their natural habitats, ecological restoration measures, control of invasive species, and *ex situ* conservation in botanic gardens, arboreta and seed banks; field data on the conservation status and distribution of a tree are also needed.

An important part of any conservation effort is the ability of managers and field workers to use limited resources: funds, personnel, equipments and knowledge - to their potential.

Conservation team needs to prioritise and use these resources wisely when deciding to gather information for conservation purposes (Tuxill and Nabhan, 2001). Information on how a plant population is regenerating provides a valuable data for resource management purpose and is widely used in planning for sustainable management of uneven-aged, mixed species forest (Cunningham, 2001). We cannot talk of conservation of plants genetic resource without knowing our stocks and their status (Msafili, 1996). As in comparison and prioritising species for management, it is important to consider the range of threats that a plant or biotic community is facing (Tuxill and Nabhan, 2001). However, our knowledge of the distribution and population size for plants growing in many parts of the world is scientifically incomplete (Briggs and Walters, 1997). More comprehensive evaluation of the conservation status of tree species for many countries would add significant numbers of species to the list of globally threatened tree species. However, evaluating the global conservation status of the world's trees is clearly a major undertaking and has only been possible through collaboration with a wide range of experts and institutions with local knowledge of tree biodiversity. For example, IUCN use quantitative criteria which are based on population trend and distribution, geographic range and quantitative analysis of extinction risk to determine whether a taxon is threatened or not, and if threatened, which category of threat it belongs (IUCN, 2001).

The assignment of conservation categories can be an important step in deciding priorities for conservation action. It is suggested that in developing priority conservation actions for tree species based on the categories of threat, the development of sustainable use rather than protection mechanisms *per se* should be the focus for economically valuable species which are categorized as Vulnerable based on levels of exploitation (WCMC, 2000). However, current initiatives aimed at assessing sustainability tend to focus on forests which are under some form of formal management. Such a focus ignores the many individual trees which grow in forests which are not formally managed but are used intensively by local people. Many individual trees grow outside forests, on farms, as scattered individuals in rangeland, or in small patches of woodland. Many such isolated or non-forest trees may be intensively used without being included in any formal forest management. Such a situation even applies to some valuable timber species which are traded internationally, such as many African savannah species (Cunningham, 2001).

1.2 General knowledge on *P. angolensis*

Bloodwood (*Pterocarpus angolensis* D.C) a tree species belongs to the family Fabaceae, subfamily Papilionoideae, the tree is reported to be slow growing having life expectancy between 60 to 90 years (NTSP, 1995). The tree experiences leaf fall early at the start of the dry season. Its flowers are orange to yellow and occur in large, branched sprays about 10 to 20 cm long. The fruits of *P. angolensis* are pods covered with spiny bristles and surrounded by orbicular, slightly lobed wings. The entire fruit is between 50-150 mm in diameter, and carried on a stalk about 10 mm in length. Pods generally contain a single seed although this may change with location. *P. angolensis* begins to produce flowers at about 20 years of age, but fruiting is late until 35 years (NTSP, 1995). Under favourable environmental conditions, the trees can grow to 25 m in height and 1 m in diameter (Goldsmith and Carter, 1981).

P. angolensis is reported to be fire tolerant, making it an important species for enrichment planting in areas where fire cannot be excluded completely. Although the tree is very resistant to fire, repeated heavy burning produces a 'stag head' appearance, which also occurs if the tree is stressed as a result of unfavourable conditions such as shallow or stony soil, or too much water (WAC, 2006). Seedlings are subject to a high degree of mortality that may be caused by a variety of factors; these include damages caused by fires, nutrient deficiencies, damage by animals and intra- and interspecific competition. While the strategy of annual die-back and re-growth may protect the seedling from fire damage, annual burning retards the development of plants from the seedling to sapling stage, however, the species is said to be high fire resistant when it reaches the sapling stage (Vermeulen, 1990). *P. angolensis* does not coppice well, if at all and therefore *P. angolensis* needs to be reproduced by seeds (UNEP-WCMC, 2006). However, experiment by (Magingo and Dick, 2001) showed possibilities of germinating *P. angolensis* from leafy stem cuttings harvested from four to five months old seedlings.

1.3 Economic importance of *P. angolensis*

P. angolensis has a wide range of uses including furniture making, fine joinery, flooring, decorative veneer, boat building and making musical instruments and jewellery (Chudnoff, 1984). Also it is used as medicine to cure malaria, black water fever and gonorrhoea. The bark is used as a general-purpose treatment for headaches, stomach-aches, mouth sores, and rashes

(Deborah and Karlyn, 1993). The bark also when heated in water, mixed with figs and massaged on the breast it stimulate lactation; when taken orally it treat blood in urine and relieve earache. Moreover, when the bark is boiled the resulting red fluid is used in treating skin lesions and ringworms. The root is a cure for diarrhoea, bilharziasis, asthma, tuberculosis and corneal ulcers. Ripe seeds when burnt and the ashes applied to inflamed areas of the skin and bleeding gums it relieve pain (WAC, 2006).

In Zimbabwe, *P. angolensis* is reported as being used preferably by carvers for making handcrafts (Braedt *et al*., 2000). The heartwood is easily worked and takes a fine polish, it shrinks very little when drying from the green condition; this quality, together with its high durability, makes it very suitable for boat building, canoes and bathroom floors. It makes most of handsome shelving, panels, doors and window frames (WAC, 2006). ***P****. angolensis* is also mentioned as good sources of dye (Hines and Eckman, 1993).

1.4 Geographical distribution of *P. angolensis*

P. angolensis is distributed in the Southern part of Africa including: Tanzania, South Africa, Malawi, Mozambique, Zambia, Zimbabwe and Botswana (Campbell *et al.,* 1996; Dorthe *et al*., 2000). It also occurs in Democratic Republic of Congo, Namibia and Swaziland (WAC, 2006) (Figure 1). The tree occurs in the miombo woodlands but sometimes as stunted trees in wooded grassland or on mountains tops (Dorthe *et al*., 2000). It prefers red loams and deep sandy soils and grows well on soils with high permeability (Deborah and Karlyn, 1993).

In Tanzania *P. angolensis* is widespread throughout the woodlands in the coastal plains; in savannah woodlands and grasslands in Kilwa, Lindi, Morogoro and Tabora, it occurs at altitudes between zero to 1650 m a.s.l. and requires rainfall ranging from 700 to 1500 mm (Deborah and Karlyn, 1993). *P. angolensis* was once reported to have become scarce from over-exploitation during the 1960s in Ngarama North Forest Reserve in Lindi Region – Tanzania, however a small remnant patch of forest has recently been found on the eastern edge of this reserve (Clarke, 1995).

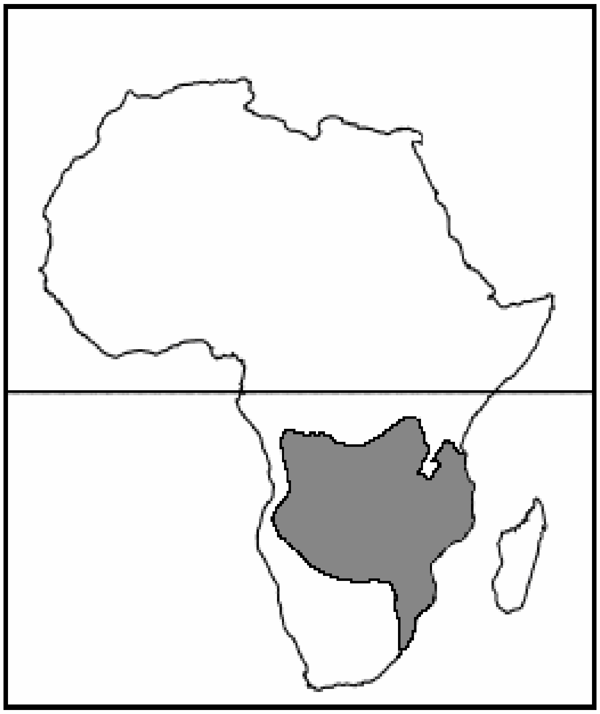

Figure 1: The natural distribution of *P. angolensis* in Africa (after Coates, 1983)

1.5 Justification

The value that a certain tree species posses usually put that species to a great disadvantage, as the species will be selectively removed from the ecosystem to offer services such as timber, charcoal, fuel wood, ornamental or handcraft. For example, Omeja ***et al.,*** (2004) found that, the high intensity of use and concentration on a limited number of the most favored drum making tree species in central Uganda resulted in their localized over-exploitation with ecological knock-on effects. Lusepani and Hangula, (2002) reports that, ***P. angolensis*** has been over-exploitation in Namibia because of the high quality timber it offers, coupled with its limited regeneration in natural stands. Furthermore, the species is subject to heavy exploitation throughout miombo woodlands of south-central Africa (Caro ***et al***, 2005).

Because of the high commercial value of its timber, ***P. angolensis*** has been cut to vulnerable population numbers (Shackleton, 2002; WAC, 2006). Based on 2001 IUCN Red List of threatened species, ***P. angolensis*** falls under Near Threatened (NT) category equivalent to LR (nt) assigned by WCMC in 1998 (World Conservation Monitoring Centre, 1998; IUCN, 2001, Vivero ***et al***., 2005). Major Threat of this species include; Habitat Loss/Degradation, Selective logging and Clear-cutting, Invasive alien species and Pathogens/parasites (World Conservation Monitoring Centre, 1998). *P. angolensis* and other hardwood species including, *Milicia excelsa, Afzelia quanzensis, Khaya anthotheca* and *Dalbergia melanoxylon* are among the miombo tree species that are commercially exploited in Tanzania, and are currently threatened by the combined forces of overexploitation plus forest degradation due to forest fires and grazing. To prevent further decline, the Tanzanian government has granted them the status of protected trees; they cannot be cut without government permission, even if they are on crop lands (Munyanziza and Wiersum, 1999). The government of Kenya had also taken some similar steps by putting some medicinal plants such as *Aloe spp.* on conservation priority list due to overexploitation. *Azadirachta indica* although widely planted is also considered threatened because of its extensive exploitation (Edwards and Zemede Asfaw, 1992).

P. angolensis suffers high human pressure as it is selectively harvested for its high quality timber (Dallu, 2002). Schwartz *et al*. (2002) found that *P. angolensis* had nearly completely depleted for the foreseeable future in Msaginia Forest Reserve in western Tanzania. Harvest intensity was leading to the rapid termination of *P. angolensis* and evidence strongly suggested that the harvest rate was unsustainable in that reserve. According to their study loggers had harvested a total of 7.7 trees/ha, reducing population density from 11.4 to 3.7 trees/ha. Trees were left standing because they were not of harvestable size yet. They further found that, *P. angolensis* faced lack of regeneration within heavily protected areas due to ungulates seedlings removal, also faced unsustainable harvest in lightly protected areas, and wholesale removal in areas that enjoyed no legal protection. Misana, (1999) in her work on deforestation issues in Kahama district northwest-Tanzania found that, the species had already been depleted in unprotected areas and it was by then illegally obtained from Forest Reserves. Madulu, (2001) had the same observation in his study in Swagaswaga Game Reserve-Kondoa District central-Tanzania, he found out that selective cutting of *P. angolensis* was observed almost everywhere in that reserve. The tree species had almost been exhausted leading to a change into the cutting of the less preferred species such as *Brachystegia spiciformis*.

While Tanzania possesses a variety of different forests, they are generally in small patches but of great importance for conservation of biological diversity. Nevertheless, protection in some of the forests is generally insufficient. The country's system of reserves doesn't include a large number of important sites and habitats, many of which are under serious threats and some are already deprived of their important tree species (Stuart *et al.,* 1990). Nguru ya Ndege Forest Reserve being a small reserve is surrounded by local communities from all sides. Prior to this study it was reported that; Local communities put pressures on the reserve's biological and ecological resources through tree felling and encroachment. Fires were reported to occur every year on the reserve's surroundings. The northwest slope of the reserve was reported as being already completely deforested and its entire valued tree species including *P. angolensis* been wiped out in that part (CELP, 2003). Before this study, few researches had been conducted in this reserve and no research was on investigating the natural stands of different plant species, and little was known on the status of individual plant species in this reserve. This study therefore aimed at assessing the status of *P. angolensis* in Nguru ya Ndege Forest Reserve, based on the assumptions that, fires, tree felling and other human disturbances have impact on the regeneration potential of this species.

1.6 Objectives of the study

1.6.1 General objective

- To assess the status of *P. angolensis* in Nguru ya Ndege Forest Reserve, Morogoro-Tanzania

1.6.2 Specific objectives

- To determine the spatial distribution of *P. angolensis* in Nguru ya Ndege Forest Reserve, Morogoro-Tanzania
- To examine the population structure of *P. angolensis* in Nguru ya Ndege Forest Reserve, Morogoro-Tanzania
- To assess the density of *P. angolensis* in Nguru ya Ndege Forest Reserve, Morogoro-Tanzania
- To assess the extent of exploitation of *P. angolensis* in Nguru ya Ndege Forest Reserve Morogoro-Tanzania

2 MATERIAL AND METHODS

2.1 Study area

2.1.1 Location

Nguru ya Ndege Forest Reserve covers an area of 36.14 km^2, (2407 ha), it is found between 6^0 - 41' – 6^0- 44' S, 37^0- 35' – 37^0- 37' E in Morogoro District, Morogoro Region-Tanzania. The reserve covers the slopes and ridges of an isolated hill north of the Uluguru Mountains on the west side of the Morogoro to Dodoma road (Lovett ***et al.***, 1995; CELP, 2003), Figure 2.

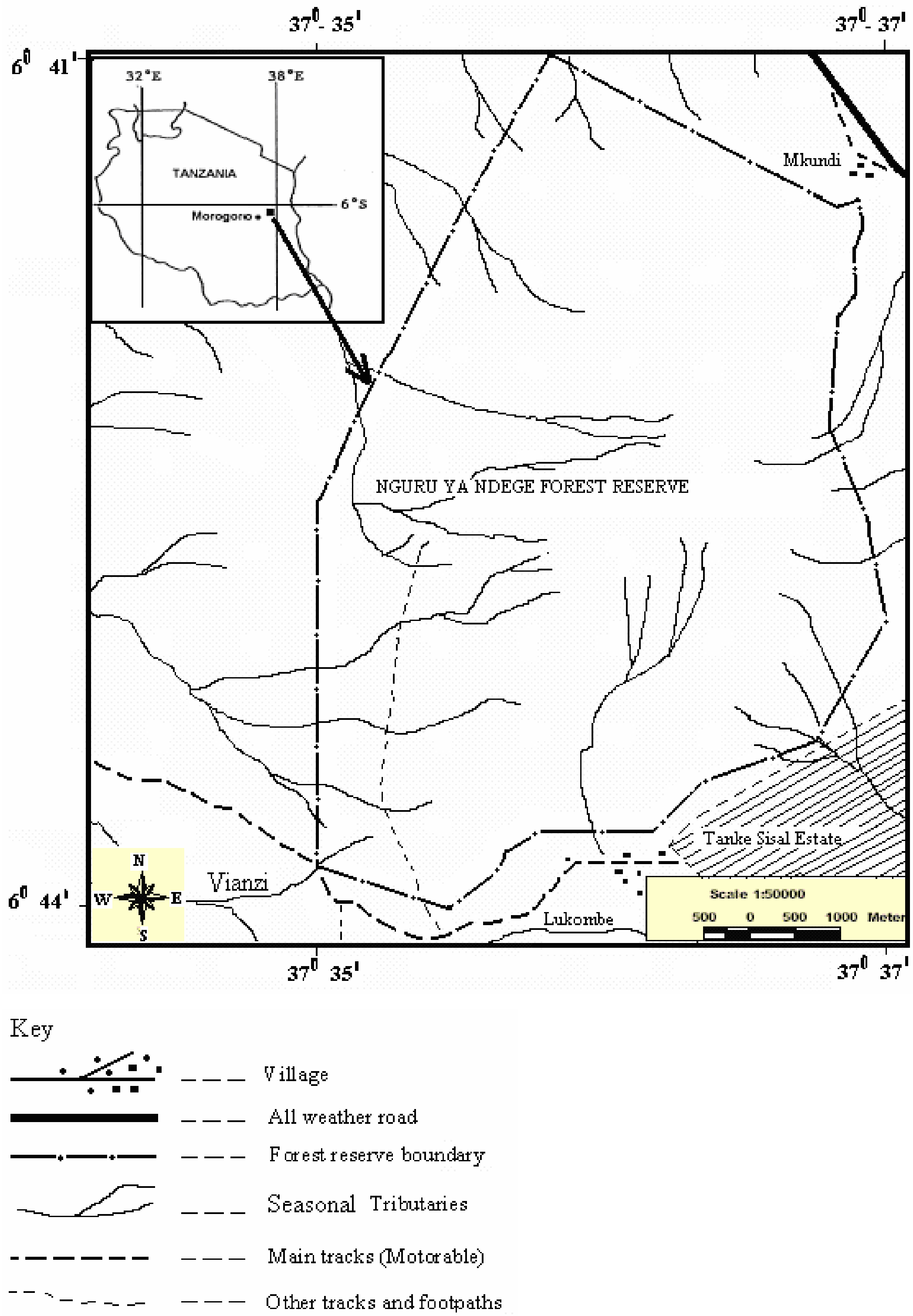

Figure 2: Map showing location of the study area

Source: (NTSP, 1995)

2.1.2 Climate

Nguru ya Ndege Forest Reserve, receives an estimated rainfall of 850mm/year and experience dry season from June to November; the temperature ranges from 25°C max. (December) down to 20°C min. (July) (CELP, 2003).

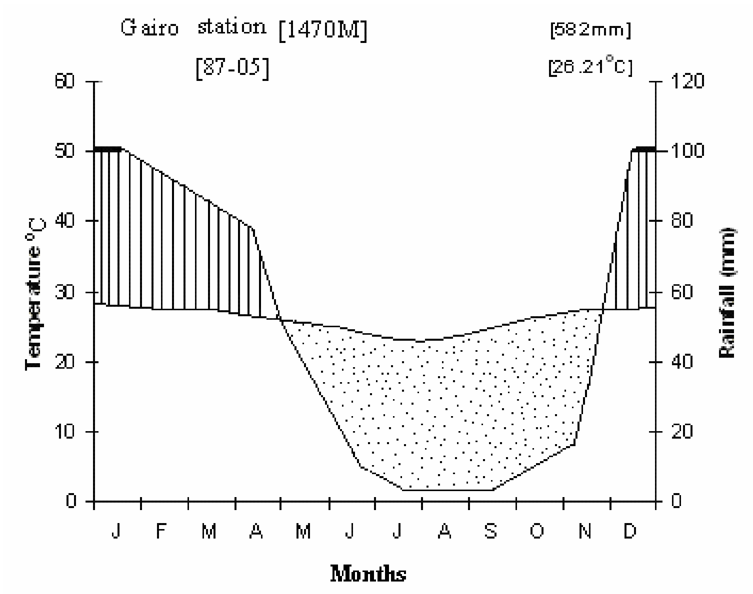

Figure 3: Climatic diagram for Nguru ya Ndege Forest Reserve
Source: Tanzania meteorological Agency, Gairo station (1987-2005)

2.1.3 Vegetation

Nguru ya Ndege Forest Reserve is composed of the woodlands as the main vegetation type, covering about 60% of the reserve's area (Lovett ***et al.,*** 1995; CELP, 2003). Previous studies reported the area to be dominated by; ***Brachystegia microphylla, B. boehmii*** and ***Julbernardia globiflora***. Some other trees included: ***Albizia harveyi, Brachystegia spiciformis, Pterocarpus angolensis, Sterculia africana, S. quinqueloba*** and ***Xeroderris stuhlmannii***. Important timber species in the reserve were reported to be ***Brachystegia spp., Pterocarpus angolensis*** and ***Afzelia quanzensis*** (Lovett ***et al.,*** 1995).

2.2 Reconnaissance survey

Reconnaissance survey was done in August 2005 in order to familiarize with the study site. During this period easy access routes to reach each of the sampling plots was established based on location of study points on the map.

2.3 Sampling of vegetation

Simple random sampling method was applied in sampling of vegetation. Using a map, the reserve was divided into equal units (Figure 4). Fifty points were then selected randomly from the established units using the method described by Williams, (1991). After the points have been selected, their geographical coordinates on the map were established. In the field the 50 selected points were located using GPS (Global Positioning System) based on the coordinates read from the map. After locating a point in the field, a 20 by 20 m quadrat was then established at the left hand corner where the coordinates meet. In each quadrat, diameter at breast height (DBH), crown diameter and height of mature and saplings of *P. angolensis* and associated woody species were recorded following the method described by Cunningham, (2001). The basal diameters of trees with DBH $\geq$ 4 cm were also measured for use in developing an equation for calculating the DBH of felled trees (Luoga *et al.,* 2002; Luoga *et al.,* 2004). Heights were measured using Clinometer (Williams, 1991) while DBH were taken by using a diameter calliper. The number of individual plants in the quadrats were also recorded (Cunningham, 2001). Stumps of the cut *P. angolensis* and other species were identified and their diameters measured. Criteria to identify species from the stumps were leaves of coppice re-growth, wood and bark characteristics (Luoga *et al.,* 2002) by the help of local people. The stumps which could not be identified were also counted.

A 5 by 5 m quadrat was then established within a 20 by 20 m quadrat for measuring and counting the shrubs and seedlings of *P. angolensis* and associated wood species (Kent and Coker, 1992). Individual plants whose DBH was < 1 cm were regarded as seedlings. Seedlings were considered as newly established plants that have not yet been damaged and thus have never re-sprouted. Individuals with DBH 1 $\leq$ 10 cm were regarded as saplings, trees were taken as individuals with DBH greater than 10 cm (Jones, 2004).

Voucher specimens were collected and identification of the plants was done in the herbarium at the University of Dar es salaam, Botany Department (Appendix 1).

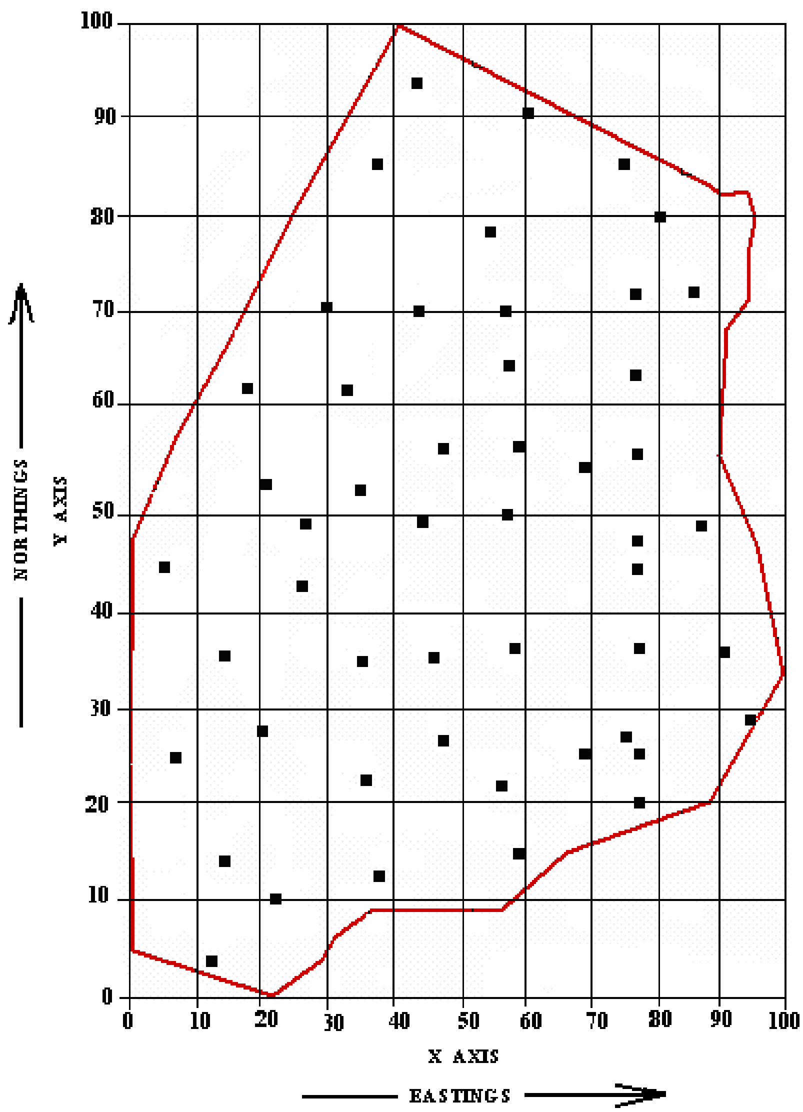

Figure 4: Map of the reserve showing grids and points used for random sampling of the study units: Modified after Williams, (1991)

2.4 Data analysis

The data was entered in Microsoft Excel to create data files and sorted to generate; plant size class distributions, plant population densities, plant canopy areas, and basal area of plants and stumps recorded. Both inferential and descriptive methods were used for statistical analysis of the data.

In order to determine the status of *P. angolensis* in the reserve, the parameters calculated on *P. angolensis* (i.e. canopy area, IVI and density) were compared with the first ten common species recorded in the reserve, this approach was also used by Simon Shibru and Girma Balcha, (2004). The common species were determined using the important value index (IVI).

Basal Area (BA) was calculated from DBH following Martin, (1995) as follows:

$BA = \pi \, (DBH/2)^2$

Where DBH= Diameter at breast height and

π is a constant = 3.14

The DBH also were used to categorize the common tree species into 10 classes: Class 1 DBH 0-4.9 cm, Class 2 DBH 5-9.9 cm, class 3 DBH 10-14.9 cm, class 4 DBH 15-19.9 cm, class 5 DBH 20-24.9 cm, class 6 DBH 25-29.9 cm, class 7 DBH 30-34.9 cm, class 8 DBH 35-39.9 cm, class 9 DBH 40-44.9 cm, class 10 DBH $\geq$ 45 cm (Cunningham, 2001; Omeja *et al.,* 2004). The density of individual *P. angolensis* and other common woody species obtained from the above classification were used to plot graphs in order to asses the DBH class size distributions of these species.

DBH were also grouped into three categories to determine the density of seedlings, saplings and mature trees of *P. angolensis* and other common species following Jones, (2004) as follows;

Seedlings, individuals with DBH < 1 cm,

Saplings, individual with DBH 1 $\leq$ 10 cm,

Trees, individual with DBH > 10 cm.

The heights were categorized into 6 classes as described by Cunningham, (2001) as follows: Class 1 height <1 m, class 2 height 1-2 m, class 3 height 2-5 m, class 4 height 5-10 m, class 5 height 10-20 m and class 6 height >20 m.

Crown diameters were used to calculate the canopy area (CA) following Cunningham, (2001) as follows;

$CA = \pi W_1/2 * W_2/2 = 0.7854 W_1 W_2$

Where; W_1 = Widest canopy diameter,

W_2 = Perpendicular diameter to the widest diameter and

π is a constant = 3.14.

Stump diameters were converted into DBH using linear regression equation following Luoga ***et al.***, (2002) as follows;

$DBH = -3.17 + 0.961SD \qquad R^2 = 98.0$

where;

DHB = Diameter at breast height,

SD = stump diameter.

The DBH obtained from stump diameter conversion was used to calculate basal area for the cut ***P. angolensis*** and other common species in the reserve.

Population density was calculated as number of individual plants/ha (Mueller-Dombois and Hellenberg, 1974; Kershaw, 1979; Kent and Coker, 1992). The density of seedlings and saplings of ***P. angolensis*** and other common species recorded in the reserve were used to group these species into three classes following Simon Shibru and Girma Balcha, (2004) as follows:

Class 1: Species with 0 individual seedling and saplings ha^{-1}

Class 2: Species with 0 > 50 individual seedlings and saplings ha^{-1}

Class 3: Species with < 50 individual seedlings and saplings ha^{-1}

According to this classification, those species which are absent in the sapling and seedling stage are put in class one, those whose density is greater than zero but less than 50 are put in class 2 and those with density greater than 50 are put in class 3.

Important Value Index (IVI) was calculated as:

IVI = Relative dominance + relative frequency + relative density.

Where;

Relative dominance = (Sum of basal area of the i^{th} species / total basal area of all species) x 100.

Relative density = (Number of stems/ha of the i^{th} species / total number of stems/ha of all species) x 100.

Relative frequency = (Frequency of the i^{th} species / total frequency of all species) x 100 (Kent and Coker, 1992).

IVI for the ten common species was categorized into 5 classes following Simon Shibru and Girma Balcha, (2004) as follows:

Class 5 = IVI (<1), Class 4 = IVI (1 -10), Class 3 = IVI (10.1- 20), Class 2 = IVI (20.1- 30) and Class 1 = IVI (> 30).

ArcView version 3.2 computer software was used to plot the distribution of ***P. angolensis*** in the reserve based on GIS co-ordinates (latitude and longitude). The distribution was determined by plotting the geographical coordinates of the sampling plot into which ***P. angolensis*** was present. After the coordinates of the quadrats into which ***P. angolensis*** were recorded has been sorted out, the data were geo-referenced using ERDAS computer program and then transported to ArcView program where it was superimposed on the previously digitalized and geo-referenced reserve's map. The ArcView software was set to present bigger triangles for quadrats with large number of ***P. angolensis*** and small triangles for quadrats with small number of individual ***P. angolensis.***

Kruskal-Wallis and Dunn's multiple comparisons tests were used to test the significant differences between parameters recorded on ***P. angolensis*** and other common species in the reserve.

- DBH class distribution, height classes, canopy structure and density of seedlings, saplings and mature trees were used to determine the population structure of ***P. angolensis*** in the reserve.
- Basal area obtained from stump diameter conversion was used to estimate the level of

exploitation of *P. angolensis* in the reserve based on basal area/ha.

- The densities of *P. angolensis* in the quadrats were converted into density/ha in order to determine the density/ha of this species in the reserve. IVI classes and density of seedlings and saplings of *P. angolensis* and other common woody species were used to determine the conservation priority of these species in the reserve.
- The ArcView plot was used to determine the spatial distribution of *P. angolensis* in Nguru ya Ndege Forest Reserve.

3 RESULTS

3.1 Density and tree conservation priority

3.1.1 Population density of *P. angolensis* in Nguru ya Ndege Forest Reserve

A total of 102 woody species was recorded in the reserve falling in 71 genera and 30 families (Appendix 1). The area was dominated by *Brachystegia microphylla, Julbernardia globiflora* and *Brachystegia boehmii.* Other common species included *Diplorhynchus condylocarpon, Combretum molle, Pteleopsis myrtifolia, Lannea welwitschii, Dalbergia boehmii, Pterocarpus angolensis* and *Acacia nilotica*. The population density of *P. angolensis* in Nguru ya Ndege Forest Reserve was 19 stems/ha for individuals with DBH ≥ 4 cm. This minimum DBH was selected because most of smaller tree are not resistant to annual fires in miombo woodlands (Kiell and Lund, 1990). The population density of individual *P. angolensis* and other common species having DBH ≥ 4 cm encountered during the study is presented in Table 1 below. The results showed that, of the ten common species *P. angolensis* took 7.69% of the total density. This density (19 stem/ha *P. angolensis*) was higher compared to that of *Acacia nilotica* 10 stem/ha (4.05%), *Dalbergia boehmii* 14 stem/ha (5.67%) and *Lannea welwitschii* 13 stem/ha (5.26%). However, *D. condylocarpon* had the highest density of 50 stem/ha (20.24%) of all the ten common species in the reserve.

Table 1: Population density of individual *P. angolensis* and other common species with DBH ≥ 4 cm recorded in Nguru ya Ndege Forest Reserve

Species	Density/ha	%
Pterocarpus angolensis	19	7.69
Brachystegia boehmii	32	12.96
Brachystegia microphylla	36	14.57
Combretum molle	24	9.72
Dalbergia boehmii	14	5.67
Acacia nilotica	10	4.05
Diplorhynchus condylocarpon	50	20.24
Julbernardia globiflora	30	12.15
Lannea welwitschii	13	5.26
Pteleopsis myrtifolia	19	7.69
Total	**247**	**100.00**

3.1.2 Tree conservation priority

3.1.2.1 IVI classes for species conservation priority in Nguru ya Ndege Forest Reserve

The IVI classes for the ten common species and the list of species under each IVI priority classes are presented in Tables 2 and 3 respectively. The classification of the ten common species under conservation priority classes revealed that *P. angolensis* fallen in class 4. None of the common species fallen in class 1 and 5 for both classification criteria.

Table 2: IVI classes for the ten common species recorded in Nguru ya Ndege Forest Reserve following Simon Shibru and Girma Balcha, (2004)

IVI classes and values	Species
5 (<1)	Nil
4 (1 -10)	*Lannea welwitschii* *Dalbergia boehmii* *Pterocarpus angolensis* *Acacia nilotica*
3 (10.1- 20)	*Julbernardia globiflora* *Brachystegia boehmii* *Diplorhynchus condylocarpon* *Combretum molle* *Pteleopsis myrtifolia*
2 (20.1- 30)	*Brachystegia microphylla*
1(> 30)	Nil

Table 3: List of the ten common species under IVI priority classes following Simon Shibru and Girma Balcha, (2004)

IVI Priority classes				
5	4	3	2	1
NIL	*L. welwitschii* *D. boehmii* *P. angolensis* *A. nilotica*	*J. globiflora* *B. boehmii* *D. condylocarpon* *C. molle* *P. myrtifolia*	*B. microphylla*	NIL

3.1.2.2 Density of seedlings and saplings of *P. angolensis* and other common species recorded in Nguru ya Ndege Forest Reserve

List of the ten common species classified under regeneration status group considering number of individual seedlings and saplings/ha are presented in Table 4. The grouping of individual seedlings and saplings/ha of *P. angolensis* and other common species under regeneration status group showed no individual in class 1. *P. angolensis* fallen in class 2 while the rest of the other common species fallen in class 3.

Table 4: List of the ten common species classified under regeneration status considering number of individual seedlings and saplings/ha following Simon Shibru and Girma Balcha, (2004)

Regeneration status		
Class 1	**Class 2**	**Class 3**
0 individuals ha $^{-1}$	**0 > 50 Individuals ha $^{-1}$**	**< 50 Individuals ha $^{-1}$**
NIL	*P. angolensis*	*B. microphylla* *D. condylocarpon* *J. globiflora* *B. boehmii* *D. boehmii* *A. nilotica* *P. myrtifolia* *C. molle* *L. welwitschii*

3.2 Population structure of *P. angolensis* in Nguru ya Ndege Forest Reserve

3.2.1 DBH class size distribution of *P. angolensis* and other woody species

The class size distribution of *P. angolensis* and other woody species recorded during the study are presented in Figure 5. Results showed that, for *P. angolensis*, there were more individuals in first class with an abrupt drop from class 5-9.9 cm DBH. The number kept lesser in middle classes with a slight increase from 10 through 19.9 cm DBH and then a drop as from 20 cm DBH showing no individuals beyond 34.9 cm DBH. This trend, where more individuals showed in lower classes with abrupt drop towards middle and upper classes appeared similar for all the ten common species.

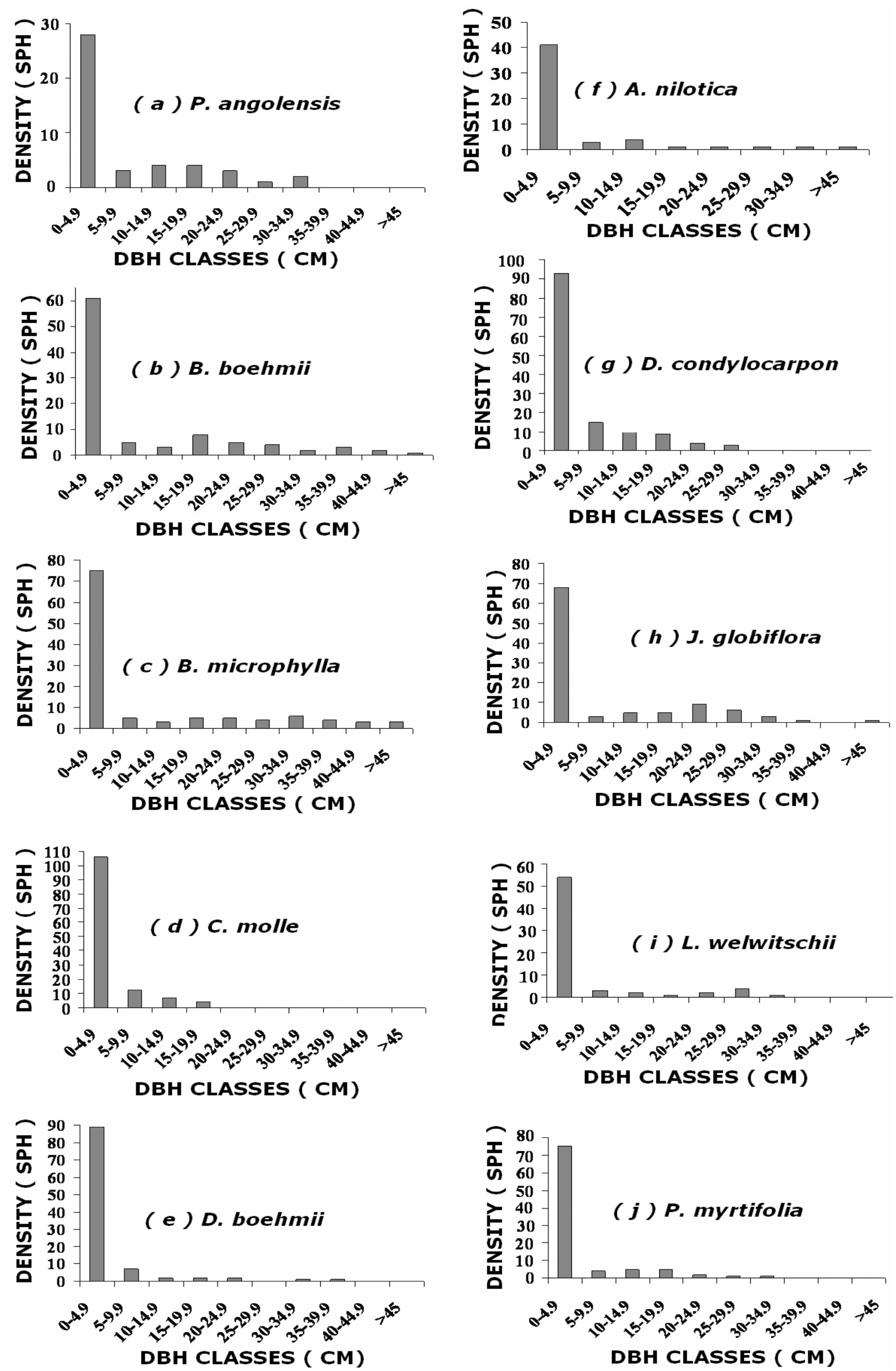

Figure 5: DBH class distribution of *P. angolensis* and other common woody species

3.2.2 Height classes of *P. angolensis*

The height classes of *P. angolensis* showing height class distribution of individuals recorded during the study are presented in Figure 6. The plotting of *P. angolensis* height classes revealed that there were more individual *P. angolensis* represented in <1 m height class. There was an abrupt drop of individuals moving from height class <1 m to 1-2 m, the number kept smaller also in class 2-5 m. An increase in number of individuals was observed in class 5–10 m. The number of individuals dropped again as from 10-20 m height class, and there were no individuals represented in height class > 20 m.

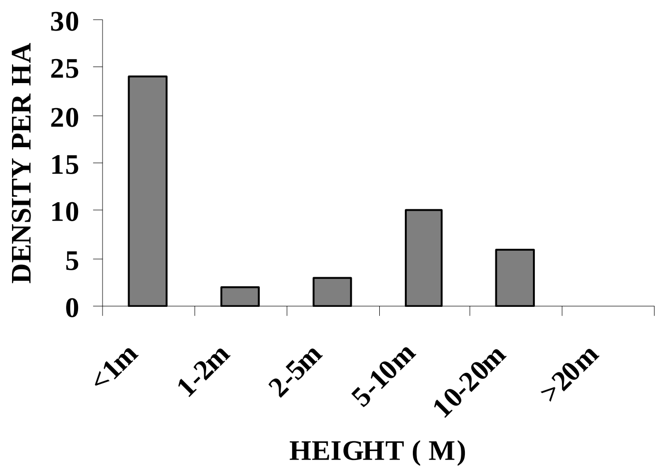

Figure 6: The height classes of *P. angolensis* showing height class distribution of individuals recorded during the study

3.2.3 The Canopy structure of *P. angolensis* and other common species recorded in Nguru ya Ndege Forest Reserve

The mean crown diameter for *P. angolensis* and other common species are presented in Table 5. Table 6 shows the mean canopy area/ha for these species while Table 7 presents Dunn's multiple comparisons test between the canopy areas of these species. The mean canopy diameter of *P. angolensis* was 3.06 m ± 0.26(SE) and its mean canopy area was 4.70 m^2 ± 0.82(SE). The mean canopy area of *P. angolensis* (4.70 m^2 ± 0.82SE) was relatively higher compared with other common species except *Brachystegia microphylla* (11.55 m^2 ± 1.46SE), *Julbernardia globiflora* (8.19 m^2 ± 0.94SE), ***Brachystegia boehmii*** *(*6.26 m^2 ± 0.79SE) and *Acacia nilotica* (5.44 m^2 ± 0.94SE). At 95% confidence interval the mean canopy area of ***P. angolensis*** lied between 3.05 m^2 and 6.35 m^2/ha. Kruskal-Wallis test revealed high significant difference between canopy areas of ***P. angolensis*** and other common species (KW = 173.09, P< 0.0001).

Table 5: Mean canopy diameter of *P. angolensis* and other common species

Name of species	**Canopy diameter ± (SE)**
P. angolensis	3.06 ± 0.26
B. microphylla	4.82 ± 0.30
D. condylocarpon	1.80 ± 0.08
J. globiflora	4.06 ± 0.26
B. boehmii	3.52 ± 0.24
D. boehmii	1.76 ± 0.21
A. nilotica	3.30 ± 0.35
P. myrtifolia	2.77 ± 0.18
C. molle	1.68 ± 0.10
L. welwitschii	2.39 ± 0.30

Table 6: Mean canopy area/ha (m^2) for *P. angolensis* and other common woody species recorded in Nguru ya Ndege Forest Reserve. (Abbreviations: PT. AN = *Pterocarpus angolensis,* DI. CO = *Diplorhynchus condylocarpon,* CO. MO = *Combretum molle,* JU. GL = *Julbernardia globiflora,* BR. BO = *Brachystegia boehmii,* BR. MI = *Brachystegia microphyll,* AC. NI = *Acacia nilotica,* DA. BO = *Dalbergia boehmii,* PT. MY = *Pteleopsis myrtifolia* and LA. WE = *Lannea welwitschii*)

	PT. AN	**BR. BO**	**BR. MI**	**CO. MO**	**DA.BO**	**AC. NI**	**DI. CO**	**JU. GL**	**LA. WE**	**PT. MY**
Mean	4.70	6.26	11.55	1.37	1.85	5.44	1.51	8.19	3.40	3.42
Standard deviation (SD)	5.24	6.49	12.53	1.48	3.31	4.30	1.41	7.78	5.19	2.92
Std. error of the mean (SEM)	0.82	0.79	1.46	0.17	0.53	0.94	0.14	0.94	0.89	0.04
Lower 95%conf. limit	3.05	4.69	8.64	1.04	0.78	0.40	1.23	6.31	1.58	2.47
Upper 95% conf. limit	6.35	7.84	14.46	1.72	2.93	13.74	1.79	10.08	5.21	4.37

Table 7: Dunn's multiple comparisons test between the canopy area of *P. angolensis* and other common species recorded in Nguru ya Ndege Forest Reserve

Comparison	**P. value**
P. angolensis VS *B. boehmii*	ns P>0.05
P. angolensis VS *B. microphylla*	ns P>0.05
P. angolensis VS *C. molle*	***P<0.001
P. angolensis VS *D. boehmii*	** P<0.01
P. angolensis VS *A. nilotica*	ns P>0.05
P. angolensis VS *D. condylocarpon*	** P<0.01
P. angolensis VS *J. globiflora*	ns P>0.05
P. angolensis VS *L. welwitschii*	ns P>0.05
P. angolensis VS *P. myrtifolia*	ns P> 0.05

Key:

*** Extremely significant (P value <0.001)

** Significant (P value <0.01)

ns Not significant (P value >0.05)

3.2.4 Population density of seedlings, saplings and mature trees of *P. angolensis* and other common species recorded in Nguru ya Ndege Forest Reserve

The density distribution of seedlings, saplings and mature trees across the ten common species recorded in Nguru ya Ndege Forest Reserve are presented in Figure 7. The plot of the distributions of seedlings, saplings and mature trees showed the least number of seedlings/ha for *P. angolensis* of all the ten common species recorded in the reserve. The twenty four seedlings/ha of *P. angolensis* was far less compared to that of *C. mole* and *D. condylocarpon* (88/ha) respectively. The number of saplings for *P. angolensis* (7/ha) did not differ much from that of *J. globiflora* (8/ha), *P. myrtifolia* (8/ha), *B. boehmii* (9/ha), *B. microphylla* (9/ha) and *L. welwitschii* (9/ha) but was much lower compared to that of *C. molle* (31/ha). *P. angolensis* showed high number of mature trees (13/ha) as compared to some other common species such as *D. boehmii* (5/ha) and *A. nilotica* 6/ha, but this number (13 stem/ha *P. angolensis*) was much low compared to that of *B. microphylla* 30 mature trees/ha.

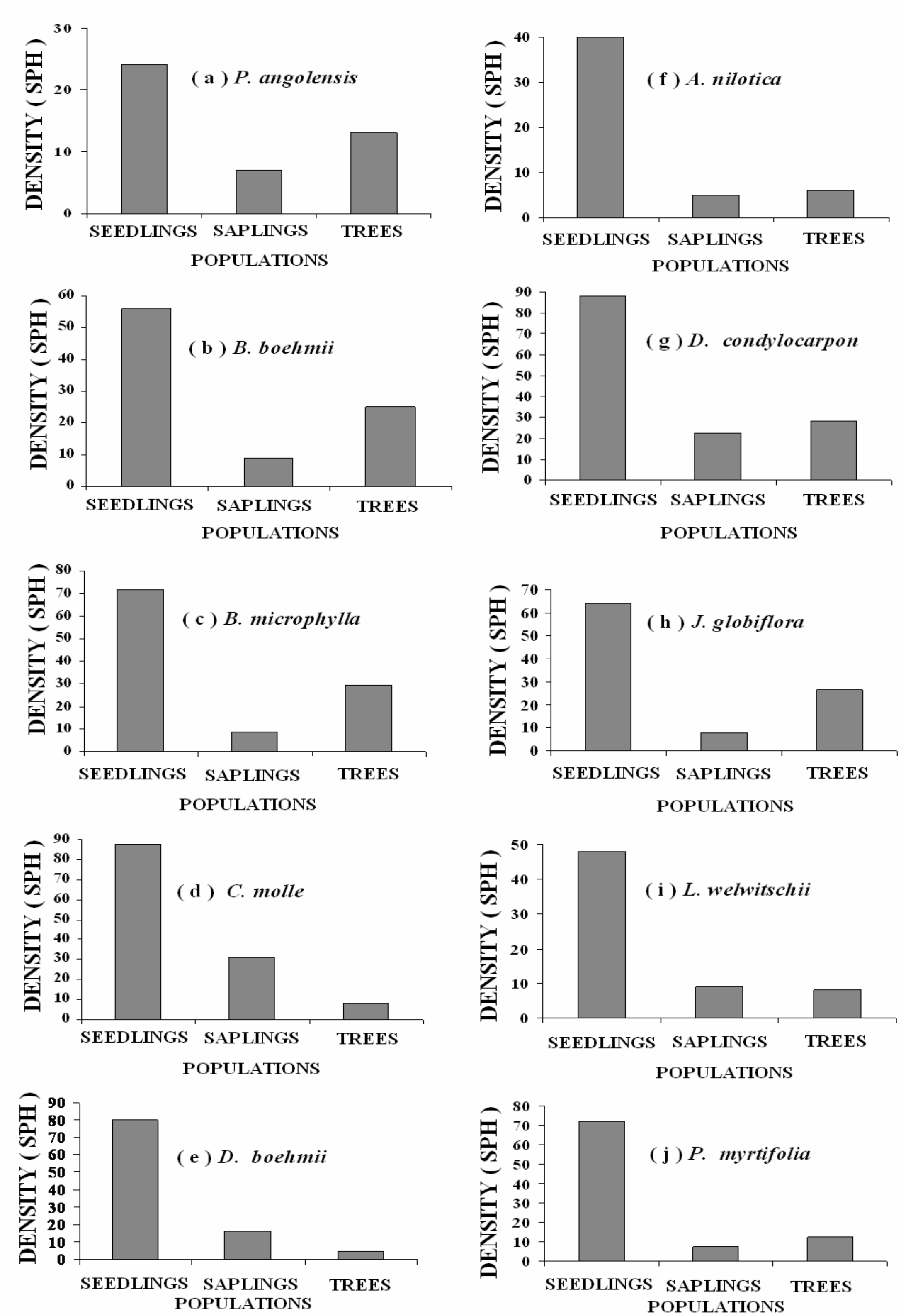

Figure 7: The population density of seedlings, saplings and mature trees of *P. angolensis* and other common woody species recorded in Nguru ya Ndege Forest Reserve

3.3 The extent of exploitation of *P. angolensis* in Nguru ya Ndege Forest Reserve

Harvesting rate of *P. angolensis* and other woody species was evaluated based on basal area/ha of the cut individual trees. Of the ten common species, *B. microphylla*, *C. molle*, *J. globiflora*, *P. angolensis* and *P. myrtifolia* were recorded cut. The basal area/ha for *P. angolensis* and other common woody species found cut in the reserve are presented in Table 8. During this study, some of the stumps could not be identified simply because most of them had already lost identification evidences such as barks, and had no sprouts. From this aspect, the total basal area for the harvested species seemed to be small (0.32 m^2/ha). The numbers of stumps which could not be identified as *P. angolensis* or any other species are presented in Appendix 2. Of the common species found harvested, *P. angolensis* was ranked the second (0.1044 m^2 basal area/ha) 32%, being preceded by *J. globiflora* (0.1372 m^2 basal area/ha) 43.34%. The other species were ranked lower with respect to *P. angolensis*.

Table 8: The basal area/ha for *P. angolensis* and other common woody species found harvested in Nguru ya Ndege Forest Reserve

Name	Basal area/ha (m^2)	Percentage	Rank
B. microphylla	0.0144	4.54	5
C. molle	0.0339	10.70	3
J. globiflora	0.1372	43.34	1
P. angolensis	0.1044	32.00	2
P. myrtifolia	0.0266	8.41	4
Total	**0.3165**	**100.00**	

3.4 The spatial distribution of *P. angolensis* in Nguru ya Ndege Forest Reserve

The spatial distribution of *P. angolensis* in Nguru ya Ndege Forest Reserve as displayed by ArcView version 3.2 computer software is presented in Figure 8. From the plotted map it was observed that, quadrats into which *P. angolensis* were recorded concentrated more in the higher altitudes moving to the interior; there were no individual *P. angolensis* recorded in the northern, western and southern parts of the reserve. The range at which individuals, *P. angolensis* occurred was between 600 to 1240 m a.s.l. At 95% confidence interval, *P. angolensis* occurred between 807.73 to 975.27 m a.s.l.

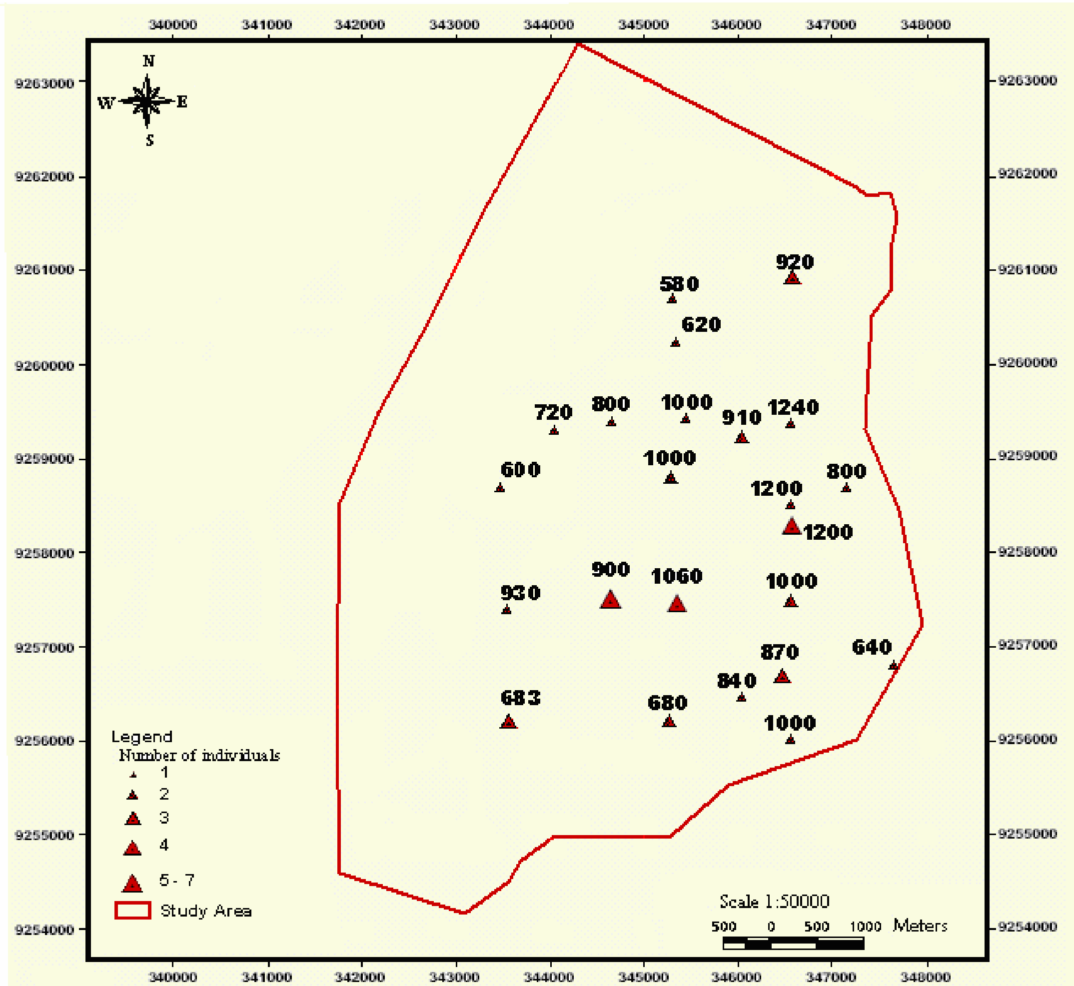

Figure 8: Map of the study area showing the distribution of quadrats into which *P. angolensis* were recorded in Nguru ya Ndege Forest Reserve as displayed by ArcView version 3.2 computer software: Numbers inside the map boundaries show the altitudes while triangles represent plots into which *P. angolensis* were recorded.

4 DISCUSSION

4.1 Density and tree conservation priority

4.1.1 Population density of *P. angolensis* in Nguru ya Ndege Forest Reserve

The density of *P. angolensis* (19 stem/ha) found in Nguru ya Ndege Forest reserve was substantially large compared to 3.67 trees/ha found by Schwartz *et al*., (2002) in Msaginia Forest Reserve in Rukwa region Tanzania. Interrogation with residents at Mkundi village revealed that people do not prefer using *P. angolensis* for other purposes except for timber sawing (Pers. com). The fact that this study recorded more *P. angolensis* in middle stages not suitable for timber sawing is the reason of why *P. angolensis* appeared to have more individual representative of DBH ≥ 4 cm compared to some other common species such as *D. boehmii*. Luoga *et al*., (2002) in his study in areas near Nguru ya Ndege Forest Reserve found that, while other species are harvested by local people for different purposes, *P. angolensis* is usually left standing until when it reaches the harvestable size for timber sawing.

4.1.2 Tree conservation priority

4.1.2.1 IVI classes for species conservation priority in Nguru ya Ndege Forest Reserve

The criteria for classifying species under conservation priority placed *P. angolensis* in class 4, this mean that, although *P. angolensis* appeared to be a common species, its IVI showed insufficient stock in this reserve compared to some other common species. According to this classification, those individual species falling in IVI priority class four or five have insufficient stocks and are recommended for conservation priority.

4.1.2.2 Density of seedlings and saplings of *P. angolensis* and other common species recorded in Nguru ya Ndege Forest Reserve

The falling of *P. angolensis* in class 2 of the regeneration status classes denote that, the species had insufficient number of seedlings and saplings to ensure its maximum perpetual in the reserve. Since none of the other common species fallen in class 1 or 2, this suggest that, either the seedlings and saplings of *P. angolensis* suffer a lot of mortality compared to other species or the regeneration potential of *P. angolensis* is insufficient in this reserve. According to this classification, those species that fall under the first and second class need a consideration for conservation priority. As *P. angolensis* fallen in class 2 when subjected to this classification, this suggest that the species need special attention for its conservation in this reserve.

4.2 Population structure of *P. angolensis* in Nguru ya Ndege Forest reserve

4.2.1 DBH class size distribution of *P. angolensis* and other woody species

The plot of *P. angolensis* DBH class distribution showed a characteristic inverted J shape although the trend seemed interrupted. This observation seemed similar for all ten common species indicating selective removal of individuals with the size of poles and mature trees either for building purpose or pit sawing. Schwartz *et al*. (2002) in their study in a forest reserve in Rukwa-Tanzania found very few individual *P. angolensis* in upper DBH classes implying that there had been selective removal of trees from their study site, and that regeneration of this species was very low. The same study developed a model, which indicated that harvest was unsustainable in that area, and they raised a serious concern about the long-term viability of this important hardwood species of the miombo woodland. They further pointed out that, interviews with local people disclosed that selective logging in that forest reserve has been on-going for over 30 years ago and that large trees for this species in that reserve have long since been felled. This same phenomenon applies for Nguru ya Ndege Forest Reserve as Wells and Wall, (2005) reports that, in 1970s-1980s Morogoro Region was the source of much of the hardwood timber including *P. angolensis* going to the Dar es Salaam market. The same source continues pointing out that, after Morogoro region has been exhausted in its stock, in the early 1990s the center of *P. angolensis* production shifted to Tabora region, and even further west to Rukwa Region by the late 1990s. These earlier findings therefore denotes that, Nguru ya Ndege Forest Reserve being in Morogoro region, its quality *P. angolensis* stocks has long been extracted; the evidence being revealed from the DBH classes where only unsuitable individuals for pit-sawing, of low and middle DBH classes were recorded during this study. When logging is not controlled (Whitmore and Sayer, 1992) usually destroys mature trees through extraction. Therefore, the lack of individual *P. angolensis* in upper DBH classes is attributed to selective logging that took place some years back in Nguru ya Ndege Forest reserve.

Newton, (1996) argues that, the cases where very few trees are recorded in the smaller size classes, removal of the largest trees could have a very severe effect on the species population status. This argument coincides with the findings on ***P. angolensis*** by this study in Nguru ya Ndege Forest Reserve; where only few individuals represent the species in its seedling stage as compared to other common species in the same area, and yet it faces selective removal from its upper classes. Thus, if this trend of unsustainable harvest continues in Nguru ya Ndege Forest Reserve, it is likely that the knock-off effect of the forest valuable individual tree species including ***P. angolensis*** will occur within a short span of time.

4.2.2 Height class of *P. angolensis*

The plot of height class distribution for ***P. angolensis*** as for its DBH class distribution showed an interrupted pattern. Big density of individuals in <1 m class is a results of sprouts of seedlings which where in the underground dormant state during dry season (as a result of shoot die back) and could not be damaged by burning fires. Vermeulen, (1990) argues that, the strategy of annual die-back and re-growth protects the seedlings of ***P. angolensis*** from fire damages. Therefore as the rain set in, individual seedlings which were in the dormant underground stage boomed up and accounted for that big density of ***P. angolensis*** in the first class as compared to the subsequent classes. The few individuals represented in class 1-2 m and 2-5 m is a result of mortality brought about by disturbances from tree logging activities and fires, as Kiell and Lund, (1990) report that, smaller trees are not resistant to annual fires in miombo woodlands. Since individual trees of less than 5 m are not taller enough to secure their shoots from annual fires, most of them die while few escape to heights suitable to survive. The increase in density in class 5-10 m is due to the fact that, individuals in this class are at sapling stages and are stronger enough to tolerate interference brought about by tree felling activities and are resistant to annual fires, as Vermeulen, (1990) report that, ***P. angolensis*** is high fire resistant when it reaches the sapling stage. Drop in density as from class 10-20 m is an indication of selective cutting of mature ***P. angolensis*** for timber sawing. ***P. angolensis*** can grow up to 25 m in height under favourable environmental conditions (Goldsmith and Carter, 1981). Thus, the absence of individuals above 20 m height either is due to unfit environmental conditions or all mature trees above that particular height are selectively removed.

4.2.3 The Canopy structure of *P. angolensis* and other common species recorded in Nguru ya Ndege Forest Reserve

According to this study it can be stated that, *P. angolensis* had relative bigger canopy area compared to some of other common species in Nguru ya Ndege Forest reserve. Cunningham, (2001), asserts that, the canopy area of the tree species shows the ground area covered by that particular species. Jones, (2004) points out that the canopy of an individual tree species has greater influence on the understorey growth of vegetations. While this study has revealed big canopy area for *P. angolensis* (see plate 2) compared to some other tree species, literature do not show whether its canopy influences either the germination or survival of its own seeds or seedlings. Since the scope of this study did not include aspect of investigating the influence of *P. angolensis* on understorey growths, this factor was not studied.

Plate 1: The canopy view of *P. angolensis* in Nguru ya Ndege Forest reserve

4.2.4 Population density of seedlings, saplings and mature trees of P. angolensis and other common species recorded in Nguru ya Ndege Forest Reserve

The least number of seedlings of ***P. angolensis*** observed among the ten common species in the reserve is a result of a collective number of factors including; disturbances brought about by tree felling (see plate 2a), shoot die back and fires. van Daalen, (1991) reports that very high intense fires reduce the viability of the seeds of ***P. angolensis.*** The frequent fires that are reported in Nguru ya Ndege Forest Reserve (Pers. com) could be killing more seeds, thus allowing only few of them to germinate. Disturbance by activities involved during trees felling for timber sawing (see plate 2b) contributes in killing young seedlings as logging was observed almost everywhere in the reserve especially on lower altitudes. Omeja ***et al***, (2004) argues that human disturbance influence seed dispersal mechanisms, fruiting, germination and regeneration of tree species. Mwitwa, (2004) asserts that ***P. angolensis*** experiences shoot die-back that takes place in all seedlings growing under field conditions. He argues that, the seedling container in such situations seemingly contains no sign of the presence of a plant. He further describes shoot dieback in ***P. angolensis*** as the gradual and seasonally permanent termination of leaf and stem life processes that occur during the cool and dry tropical seasons. Considering this phenomenon, and the fact that during data collection it rained just for a short period in the study area, probably most of the seedlings were present in their dormant underground stage and could not be noticed. In general, since fires and tree felling were observed to be common phenomena in the reserve, these combined with inevitable shoot die back of the species are the reasons of why small number of seedlings for this species was recorded.

Plate 2: (a) The stump of cut *P. angolensis* in Nguru ya Ndege Forest reserve, (b) Timber found hidden after being sawn in Nguru ya Ndege Forest reserve

The seedlings for all ten common species in a general look were seemed to suffer immense mortality before reaching the sapling stage; (either due to fires or damages from tree tracking humans or injuries from rolling logs, or all of these combined together), or the saplings are removed from the reserve for different purposes such as houses construction or instruments making. This argument is supported by small densities of saplings as related to the densities of seedlings for all the ten common species. The observed slightly high density of mature *P. angolensis* (13 stem/ha) compared to some other common species was due to the fact that, these individuals were either unsuitable for pit sawing with bent trunks or had undesirable low DBH, or were located in areas not easily accessed by tree fellers such as the eastern steeply sides of the reserve.

4.3 The extent of exploitation of *P. angolensis* in Nguru ya Ndege Forest Reserve

It is interesting to note, however, the perceived impact of felling as a major threat to tree species; Threats include both clear felling and selective felling (WCMC, 2000). Use of a tree species may result in a decline in the area of occupancy and the number of mature individuals of that species (IUCN, 1994). Regardless of the small basal area for the tree species found harvested in the reserve, ***P. angolensis*** seemed to be removed more as it contributed for high percentage of the total basal area compared with the rest of the ten common species found cut, not considering ***J. globiflora***.

4.4 The spatial distribution of *P. angolensis* in Nguru ya Ndege Forest Reserve

From the plotted Arcview map it was observed that the distribution of ***P. angolensis*** in the reserve was not even. The absence of ***P. angolensis*** especially in the northern, western and southern parts of the reserve was a result of selective logging and fires in those areas, or edaphic factors. The eastern parts of Nguru ya Ndege Forest Reserve consists of steep slopes and bad terrain; these are the reasons why some plots consisting ***P. angolensis*** were found just close to the boundary of the reserve in this part. Tree loggers might be experiencing difficulties in accessing this area.

According to Lovett ***et al***, (1995), the edges of Nguru ya Ndege Forest reserve face fire incidences, deforestation for charcoal making and tree cutting for timber sawing. The villagers at Mkundi and Lukombe also disclosed that people prefer poaching trees for charcoal making (see plates 3 and 4) and timber sawing just few hundreds of meters from the edges of the reserve in fear of the forest officers who usually conduct ambush patrols (Pers. com). These incidents, where people concentrate on cutting trees at the edges of the reserve combined with frequent fire occurrences in the same areas are the roots of deprived re-establishment and the mortality of seedlings and hence the cause of the nonexistence of individual ***P. angolensis*** in those particular areas. Vermeulen, (1990) asserts that, although ***P. angolensis*** is resistant to fires, heavy and/or frequent fires damages seedlings and prevent them passing to sapling stage.

Plate 3: Pieces of wood found cut for charcoal burning in Nguru ya Ndege Forest reserve

Plate 4: The kiln previously used to burn charcoal in Nguru ya Ndege Forest reserve

5 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The distribution of *P. angolensis* in Nguru ya Ndege Forest Reserve is not even, the species is only restricted in the higher altitudes of the reserve as from the centre moving to the eastern sides. The species is not found in the northern, western and southern parts of the reserve especially in areas close to the boundaries. Fires and selective logging of individual *P. angolensis* are the causes of disappearance of this species from these parts of the reserve.

The population structure of *P. angolensis* in Nguru ya Ndege Forest Reserve did not show a natural trend. The natural regeneration of the species has been altered by human activities such as fires, encroachment and tree felling; as a result the distribution of individuals in DBH classes is narrowed i.e. individuals of low and middle DBH were at least prominent while mature individuals were not well represented.

The density of *P. angolensis* in Nguru ya Ndege Forest Reserve is still considerably large as compared to the densities reported from other studies on the same species in other parts of Tanzania, although representative individuals are those not favored by tree loggers - of low DBH and unsuitable trunks for timber sawing.

Mature individuals of *P. angolensis* in Nguru ya Ndege Forest Reserve are being over-exploited by selective removal for timber sawing.

Generally, the store of *P. angolensis* in Nguru ya Ndege Forest Reserve is still promising; its population structure might show a normal trend in future if the reserve is put in a well-managed regime to allow individuals in low DBH classes make it to mature reproductive ones. Above all, *P. angolensis* deserves a special priority for its conservation in this reserve.

5.2 RECOMMENDATIONS

For better conservation and management of *P. angolensis* in Nguru ya Ndege Forest Reserve, the following are recommended:

- Nguru ya Ndege Forest Reserve should be transplanted with seedlings of *P. angolensis* especially in the northern, western and southern parts in order to restored those denuded areas of the reserve.
- The Forestry Department in Morogoro should provide awareness education to people surrounding Nguru ya Ndege Forest Reserve on the ecological and economical importance of *P. angolensis*. As this may help to reduce pressure put by local people on this species in the reserve.
- Protection level of *P. angolensis* put by Tanzanian government; that the tree can not be cut without government permission even if it occurs on crop land should be enforced by law to ensure that this protection is executed effectively.
- Regular patrolling in the reserve is needed to stop illegal logging.
- Fire control is needed to allow regeneration of the vegetation in the reserve and to minimize seed mortality in order to attain maximum recruitment of *P. angolensis* and other species.
- Further studies to investigate regeneration potential of *P. angolensis* in Nguru ya Ndege Forest Reserve are needed.
- A study to compare dry and wet season status of *P. angolensis* is required in order to explore the species in its fully life cycle, as this will take care of the individuals which might be overlooked while in their underground dormant stage during dry seasons.
- A study to investigate if edaphic factors apart from fires and human disturbances do influence the distribution of *P. angolensis* is recommended in this reserve.

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7. APPENDICES

Appendix 1: Checklist for species recorded in Nguru ya Ndege Forest Reserve during the study

S/N	SPECIES NAME	FAMILY	HABIT
1	*Acacia goetzei* Harms.	Fabaceae	T
2	*Acacia goetzei subsp. microphylla* Brenan	Fabaceae	T
3	*Acacia nigrescens* Oliver	Fabaceae	T
4	*Acacia nilotica* (L.) Willd.ex Del	Fabaceae	T
5	*Acacia pentagona* (Schumach.)Hook.F.	Fabaceae	S
6	*Acacia polyacantha subsp. campylacantha* (Hochst. ex. A. Rich.) Brenan	Fabaceae	T
7	*Afzelia quanzensis* Welw.	Fabaceae	T
8	*Albizia harveyi* Fourn	Fabaceae	T
9	*Albizia petersiana* Oliver	Fabaceae	T
10	*Allophyllus africanus* P.Beauv.	Sapindaceae	S
11	*Annona senegalensis* Pers	Annonaceae	T
12	*Bauhinia petersiana* C. Bolle	Fabaceae	S
13	*Bombax rhodognaphalon* K.Schum.	Bombacaceae	T
14	*Boscia salicifolia* Oliv.	Capparidaceae	S
15	*Brachystegia boehmii* Taub.	Fabaceae	T
16	*Brachystegia microphylla* Harms	Fabaceae	T
17	*Brachystegia spiciformis* Benth	Fabaceae	T
18	*Bridelia cathartica* Bertol.F.	Euphorbiaceae	T
19	*Cassia abbreviata* Oliver	Fabaceae	S
20	*Catunaregam spinosa* (Thumb) Tirveng.	Rubiaceae	T
21	*Combretum adenogonium* Steud. ex A. Rich	Combretaceae	T
22	*Combretum collinum* Fresen.	Combretaceae	T
23	*Combretum molle* R.Br. ex G.Don	Combretaceae	T
24	*Combretum padoides* Engl.&Diels	Combretaceae	T
25	*Combretum zeyheri* Sond.	Combretaceae	T
26	*Commiphora africana* (A. Rich.) Engl.	Burseraceae	S
27	*Crossopteryx febrifuga* (G.Don) Benth.	Rubiaceae	S
28	*Croton macrostachyus* Hochst. ex Delile	Euphorbiaceae	T
29	*Croton megalocarpus* Hutch	Euphorbiaceae	T
30	*Dalbergia boehmii* Taub	Fabaceae	T
31	*Dalbergia melanoxylon* Guill.& Perr	Fabaceae	T
32	*Dalbergia nitidula* Baker	Fabaceae	T
33	*Dalbergia obovata* E. Mey.	Fabaceae	T
34	*Deinbollia borbonica* Scheff.	Sapindaceae	S
35	*Dichrostachys cinerea* (L.) Wight & Arn	Fabaceae	S
36	*Diospyros consolatae* Chiov.	Ebenaceae	S
37	*Diospyros kirkii* Hiern	Ebenaceae	T
38	*Diospyros mespiliformis* Hochst. ex A. DC	Ebenaceae	T
39	*Diospyros zombensis* (B.L. Burt) F. White	Ebenaceae	S
40	*Diplorhynchus condylocarpon* (Muell-Arg.) Pichon	Apocynaceae	T
41	*Dombeya cincinnata* K. Schum. ex Engl.	Sterculiaceae	T
42	*Dombeya rotundifolia* (Hochst.) Planch.	Sterculiaceae	T
43	*Drypetes gerrardii* Hutch	Euphorbiaceae	S
44	*Ehretia amoena* Klotzsch	Boraginaceae	T
45	*Erythrina abyssinica* Lam.ex DC	Fabaceae	T
46	*Erythrophleum africanum* (Benth.) Harms	Fabaceae	T
47	*Ficus bussei* Mildbr.&Burret	Moraceae	T
48	*Ficus exasperata* Vahl	Moraceae	T
49	*Ficus sycomorus* L.	Moraceae	T

50	*Garcinia huillensis* Welw	Clusiaceae	T
51	*Gardenia ternifolia* Schumach. & Thonn.	Rubiaceae	S
52	*Grewia bicolor* Juss.	Tiliaceae	T
53	*Grewia ectasicarpa* S. Moore	Tiliaceae	S
54	*Grumilea riparia* K. Schum & K. Krause	Rubiaceae	T
55	*Haplocoelum inopleum* Radlk	Sapindaceae	T
56	*Harissonia abyssinica* Oliv.	Simaroubaceae	S
57	*Heteromorpha trifoliata* (Wendl.) Eckl. & Zeyh.	Umbelliferae	S
58	*Julbernardia globiflora* (Benth.) Troupin	Fabaceae	T
59	*Kigelia africana* (Lam) Benth.	Bignoniaceae	T
60	*Lannea schimperi* (A. Rich.)Engl.	Anacardiaceae	T
61	*Lannea welwitschii* (Hiern) Engl.	Anacardiaceae	T
62	*Lecaniodiscus fraxinifolius* Bak.	Sapindaceae	T
63	*Lonchocarpus bussei* Harms	Fabaceae	T
64	*Maerua triphylla* A.Rich	Capparidaceae	T
65	*Margaritaria discoidea* (Baill.) Webster	Euphorbiaceae	T
66	*Markhamia obtusifolia* (Baker) Sparague	Bignoniaceae	T
67	*Maytenus senegalensis* (Lam.) Excell	Celastraceae	T
68	*Millettia usaramensis* Taub	Fabaceae	T
69	*Ochna leptoclada* Oliver	Ochnaceae	T
70	*Ormocarpum kirkii* S. Moore	Fabaceae	S
71	*Ozoroa insignis* Del.	Anacardiaceae	S
72	*Ozoroa reticulata* (Baker F.) R.Fern. & A.Fern.	Anacardiaceae	S
73	*Parinari excelsa* Sabine	Chrysobalanaceae	T
74	*Pavetta crassipes* K.Schum	Rubiaceae	S
75	*Pseudolachnostylis maprouneifolia* Pax	Euphorbiaceae	T
76	*Pteleopsis myrtifolia* Engl.&Diels	Combretaceae	T
77	*Pterocarpus angolensis* DC.	Fabaceae	T
78	*Pterocarpus rotundifolius* (Sond.)Druce	Fabaceae	T
79	*Pterocarpus tinctorius* Welw.	Fabaceae	T
80	*Sclerocarya birrea* (A.Rich.)Hochst.	Anacardiaceae	T
81	*Scorodophloeus fischeri* (Taub.) J. Leon	Fabaceae	T
82	*Sorindeia madagascariensis* Baill	Anacardiaceae	T
83	*Spirostachys africana* Sond	Euphorbiaceae	T
84	*Steganotaenia araliacea* Hostchst.	Apiaceae	S
85	*Sterculia africana* (Lour.) Fiori.	Sterculiaceae	T
86	*Sterculia quinqueloba (* Garcke) K. Schum	Sterculiaceae	T
87	*Stereospermum kunthianum* Cham.	Bignoniaceae	T
88	*Strychnos spinosa* Lam.	Loganiaceae	T
89	*Suregada zanzibariensis* Baill.	Euphorbiaceae	T
90	*Swartzia madagascariensis* Desv.	Fabaceae	T
91	*Synsepalum brevipes* (Baker) T.D. Penn	Sapotaceae	T
92	*Terminalia sericea* Burch. ex DC	Combretaceae	T
93	*Toddalia asiatica* Baill.	Rutaceae	S
94	*Treculia africana* Decne. ex Trecul	Moraceae	T
95	*Vangueria infausta* Burch.	Rubiaceae	S
96	*Xeroderris stuhlmannii* (Taub.) Mendoca & Sousa	Fabaceae	T
97	*Ximenia americana* L.	Olacaceae	T
98	*Ximenia caffra* Sond.	Olacaceae	T
99	*Zahna africana* (Radlk.) Exell	Sapindaceae	T
100	*Zanthoxylum chalybeum* Engl.	Rutaceae	S
101	*Ziziphus mucronata* Willd	Rhamnaceae	T
102	*Vitex payos* (Lour.) Merr.	Verbenaceae	T

Appendix 2: Number of stumps which could not be identified during the study

QUADRAT NO.	ALTITUDE (m.a.s.l)	EASTINGS	NORTHINGS	NO. OF STUMPS	*P. angolensis*
31	500	342900	9259300	3	-
10	520	343980	9261290	1	-
23	540	342980	9260000	3	-
77	558	342000	9256300	4	-
12	560	345300	6261310	3	-
49	570	342910	9258300	3	-
41	600	343400	9258700	5	+
96	610	343910	9255110	1	-
27	620	345290	9260250	7	+
76	640	347600	9256810	8	+
22	670	347100	9260970	2	-
82	680	345200	9256200	3	+
79	683	343500	9256210	6	+
33	720	343990	9259310	6	+
34	800	344600	9259400	2	+
47	800	347100	9258680	4	+
83	840	345980	9256460	2	+
74	870	346400	9256700	1	+
36	910	345990	9259230	1	-
TOTAL 19				**65**	

Key:

+ *P. angolensis* was present in that quadrat

- *P. angolensis* was absent in that quadrat

DECLRATION

I, the undersigned, do declare that, this is my original work and has not been presented for a degree in any other university and that all sources of materials used have been duly acknowledged.

Robert Modest ____________________________

Name Signature