# Demography and Dynamics of Commonly Harvested Woody Species in A Protected Forest Reserve-Western Zimbabwe

**J. Mudekwe**

Dept. of Forest and Wood Science. Faculty of Agricultural and Forestry Sciences, University of Stellenbosch, Private Bag X01 Matieland 7602, South Africa

**Corresponding Author**

J. Mudekwe
*e-mail*: mudekwe.john@gmail.com

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**Abstract**

Developing sustainable mechanisms for use-management of forests by user communities has been suggested as a possible solution to the often-observed conflict between forest use and the conservation of protected forests. In Zimbabwe, the use of forest products in protected forests by local communities has a long history, but few studies have explored the ecological aspects of this use. This study was conducted in a *Baikiaea plurijuga* forest in Fuller Forest in western Zimbabwe, protected since 1943. It explored the demography and dynamics of commonly harvested woody species in order to establish the present status of populations of these species. This examination, focusing on diameter class distributions, was aimed at informing whether species populations were expanding, stable or declining in view of their capacity to continue providing required goods and services. Results indicated that at present *Baikiaea plurijuga, Colophospermum mopane, Brachystegia spiciformis, Diplorhynchus condylocarpon, Commiphora mocambicensis* and *Bauhinia petersiana* out of 14 commonly harvested species appear to have relatively stable populations as indicated by their inverse J-shaped diameter class distribution profiles.

***Keywords:*** Demography, species, population, conservation, expanding, declining

## 1. Introduction

People surrounding protected forests harvest a wide range of tree species to obtain different products.

Characterisation of the size class distributions of harvested tree populations is useful in determining population trends with respect to stability, self-maintenance and expansion. Studies to investigate effect of harvesting practices on structure and stability of tree populations are rare in these forests, yet changes in tree population structure often take place before changes in species composition making population structure a useful indicator of use impact on woody species populations.

The harvesting of forest products for direct household provisioning and for commercial purposes might have implications for the ecology of the resources being exploited (Padoch, 1992; Peters, 1994, 1996; Momberg et al., 2000; Geldenhuys 2004). The delicate ecological balance maintained in protected forests can easily be disrupted by human intervention. Subsistence forest use practices may seem benign but in the longer term can impact severely on the structure and dynamics of the forest ecosystem (Peters 1996; Cunliffe 2000).

The intensive selection of preferred tree sizes often leads to changes in the stem diameter distribution of forest stands (Shackleton 1993b; Peters 1996). In a study in the eastern Lowveld of South Africa Shackleton (1993b) found that woody species experiencing intensive size preferences exhibited reduced numbers of size classes available and reduced individuals in particular size classes.

The Forestry Commission strongly perceives that the subsistence harvesting of the woody component in the protected forests has impacted on the population structure and composition of the species being harvested and that the populations have become unstable and cannot maintain themselves (Forestry Commission 1992). There was need to investigate whether use practices in protected forests have impacted on the population structures of species being harvested. Such information would be useful for planning harvesting yields and implementing silvicultural practices that enhance productivity of the plant resources.

To describe the size distributions of the commonly harvested tree species in Fuller protected forest the following questions were posed.

(i) What is the pattern of distribution and structure of populations of the commonly harvested woody species? (ii) Are populations of the commonly harvested woody species in a stable state? (iii) How has subsistence use impacted on the structure of the harvested woody species?

## 2. Study Area

Fuller Forest Reserve lies between Latitude $18^0$08'31" South and longitude $25^0$56'16" East. The forest reserve covers 23 300 ha. It is administered by the Forestry Commission on behalf of the state. The forest borders with Hwange Communal Area in the north and commercial game ranches in the south. The Bulawayo to Victoria Falls road and the Bulawayo to Victoria Falls railway line run along the northern and southern boundaries of the forest respectively.

The dominant climatic characteristic in the region is a short and erratic rainfall season from mid-November to mid-March. The annual average rainfall for the forest is about 550 mm (Forestry Commission 1992). There is considerable year-to-year variation, such that in some low rainfall years the annual average rainfall falls to 400 mm and in high rainfall years goes above 800 mm (PlanAfric 2000). Mean annual temperature in the study area is approximately 21.5 $^0$C. Mean monthly temperatures in the hot and cold months are about 30 $^0$C and 17 $^0$C respectively (Nyamapfene 1991).

Kalahari Sands cover the bulk of Fuller Forest. The sands comprise deep unconsolidated Tertiary Sands of Aeolian origin (Nyamapfene 1991). The Kalahari Sands are strongly uniform physically and chemically. The soils comprise well drained and deep, medium grained sands (Anderson *et al*. 1993; Lockett 1979). The sands are inherently of extreme low fertility (Nyamapfene, 1991).

The Kalahari Sands ridge in Fuller Forest supports a predominantly *Baikiaea plurijuga* forest type. The vegetation shows a distinct catenary pattern with *Baikiaea* on the ridge and *Burkea*, *Terminalia*, *Combretum mixed scrub* and occasionally *Colophospermum mopane* on escapements and in depressions. *Baikiaea* is an African genus, with five other species confined to the tropical lowland rain forests of west-central Africa, the Guinea-Congolian floral region (Huckabay 1986). The *Baikiaea plurijuga* forest formation in its present range in central southern Africa is believed to be at its environmental and climatic limits (Brummitt 1986; Huckabay 1986). It is uniquely restricted to Kalahari Sands, under an annual rainfall regime ranging from about 1000 mm in southeast Angola to about 500 mm in northwest Zimbabwe (Huckabay 1986; Wood 1986). The vegetation of the Kalahari Sands has been described by Fanshawe and Savory (1964), Huckabay (1986), Wood (1986) and Childes and Walker (1987).

## 3. Methods

The method and procedure used in this study to assess the woody component in the forest follows that of Shackleton (1993). A co-ordinate system was laid over aerial photographs of Fuller Forest. The potential sample plots were generated by simple unrestricted random selection without replacement and marked on the overlay. The sample plots were located in the field using a Global Positioning System (GPS) according to the random distribution of the plots on the overlay. Concentric circular sample plots with a radius of 12 m (452 $m^2$) and of 2 m (12.6 $m^2$) for tallying the woody component and regeneration respectively were used. Altogether 91 plots were sampled. Within each 12 m – radius plot the following parameters were recorded:

1. The diameter at breast height of each woody stem for stems equal to or greater than 2 cm. For coppices, each stem was measured separately and averaged to obtain an estimated diameter of the main rootstock. A minimum diameter of 2 cm was opted for because it was observed that considerable quantities of this size were being harvested for the construction of granaries, poultry and small livestock pens.

2. The taxonomy of each measured stem. In the 2 m – radius plots regeneration by species was tallied. Stems less than 2 cm in diameter at breast height were considered as recruitment through seed germination or through vegetative reproduction. This definition may include stems from previous seasons that had died back during the non-growing season (Chidumayo 1992a, b). The definition also provides an index of the reproductive capacity of the tree species. This definition does not include under canopy shrubs as regeneration material. The shrubs are inherently multi-stemmed and the stems are generally less than 2 cm in diameter.

Diameter size classes were determined as 5 cm increments in diameter at breast height. Class 1: 2 – 6.9 cm dbh; class 2: 7 – 11.9 cm dbh; class 3: 12 – 16.9 cm, and so on (17 –21.9 cm; 22 – 26.9 cm; 27 – 31.9 cm; 32 – 36.9 cm; 37 – 41.9 cm; 42 – 46.9 cm; 47 – 51.9 cm; 52 –56.9 cm; 57 – 61.9 cm; 62 – 66.9 cm and class 14, 67 cm and above. All stems greater than size class 14 were pooled in a single size class.

Descriptive statistics of species density, basal area, frequency, dominance and importance values were determined following Curtis and McIntosh (1952) and Kent and Coker (1992).

## 3. Results

### 3.1. Species composition

A total of 75 woody species were recorded in the forest. The demography of 23 commonest species that had a relative density greater than 1% is shown in Table 1. There is considerable variation in the descriptive statistics of these 23 species.

These 23 species constituted 91% of stems per hectare for all the species recorded in the forest.Out of these 23 species only seven, *Baikiaea plurijuga*, *Bauhinia petersiana*, *Commiphora mollis*, *Commiphora mossambicensis*, *Commiphora angolensis, Baphia massaiensis* and *Kirkia acuminata* had more than 50 stems/ha and these 7 species contributed 70% to the total relative density of all stems measured.

In the 91 sample plots (4.113 ha), there were 1439 stems/ha with diameter at breast height greater than 2 cm. There is considerable variation in stem absolute density amongst species, ranging from 1 to 483 stems/ha. The most dominant and commonest species is *Baikiaea plurijuga* with an absolute density of 483 trees/ha, a relative density of 34.9% and frequency of 78.02%.

The absolute densities of species favoured for firewood were *Baikiaea plurijuga* (483 stems/ha), *Brachystegia spiciformis* (33 stems/ha), *Colophospermum mopane* (44 stems/ha), *Combretum collinum* (23 stems/ha) and *Burkea africana* (9 stems/ha) and their frequency of occurrence ranged between 78.02% and 12.09%. Species favoured for construction poles had the following absolute densities: *Kirkia acuminata* (53 stems/ha), *Colophospermum mopane* (44 stems/ha), *Erythrophleum africanum* (41 stems/ha), *Terminalia sericea* (24 stems/ha), *Croton gratissimus* (15 stems/ha) and *Burkea africana* (9 stems/ha). Frequency of occurrence of these species was between 56.04% and 3.30%. Species favoured for woodcarving, i.e. *Pterocarpus angolensis* and *Afzelia quanzensis*had absolute densities of 13 and 6 stems/ha respectively.

The total basal area in the 91 sample plots (4.113 ha) was 81.40 $m^2$ (estimated mean 19.74 $m^2$/ha). *Baikiaea plurijuga* had the highest basal area (7.74 $m^2$) per hectare. The basal area of those species with relative density greater than 1% ranged from 0.02 $m^2$ to 7.74 $m^2$. The mean diameters at breast height of the 23 commonest species ranged from 3.1 cm to 21.6 cm (Table 1).

*3.2. Stem diameter size class distributions*

Pooled data for all stems encountered in the sample plots displayed a negative exponential stem diameter size class distribution profile (Figure 1). The stem diameter size class

Table 1: Demography of species with relative density > 1% and commonly

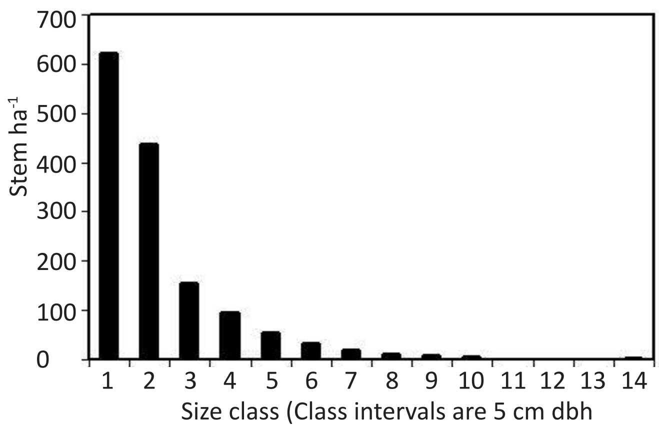
| harvested species | Stems $ha^{-1}$ | Relative density (%) | Fre-quency (%) | Basal area $ha^{-1}$ ($m^2$) | Relative dominance (%) | Impor-tance value | IV Rank | Mean dbh (cm) |
|---|---|---|---|---|---|---|---|---|
| *Baikiaea plurijuga** | 483 | 34.90 | 78.02 | 7.74 | 39.21 | 74.11 | 1 | 11.6 |
| *Kirkia acuminata** | 53 | 3.83 | 56.04 | 2.48 | 12.56 | 16.39 | 2 | 21.6 |
| *Commiphora angolensis** | 86 | 6.21 | 26.71 | 1.03 | 5.22 | 11.43 | 3 | 7.9 |
| *Bauhinia petersiana* | 135 | 9.75 | 49.45 | 0.24 | 1.22 | 10.97 | 4 | 4.0 |
| *Commiphora mollis* | 95 | 6.86 | 59.34 | 0.35 | 1.77 | 8.63 | 5 | 10.8 |
| *Erythrophleum africanum** | 41 | 2.96 | 50.55 | 0.90 | 4.55 | 7.51 | 6 | 14.7 |
| *Brachystegia spiciformis** | 33 | 2.38 | 32.97 | 0.67 | 3.39 | 5.77 | 7 | 11.8 |
| *Colophospermum mopane** | 44 | 3.17 | 12.09 | 0.43 | 2.18 | 5.35 | 8 | 9.3 |
| *Commiphora mocambicensis* | 55 | 4.05 | 19.78 | 0.23 | 1.17 | 5.22 | 9 | 6.5 |
| *Baphia massaiensis* | 57 | 4.12 | 29.67 | 0.08 | 0.41 | 4.53 | 10 | 3.9 |
| *Brachystegia boehmii* | 34 | 2.46 | 2.19 | 0.18 | 0.91 | 3.37 | 11 | 10.4 |
| *Terminalia sericea** | 24 | 1.79 | 35.16 | 0.23 | 1.17 | 2.96 | 12 | 9.2 |
| *Guibourtia coleosperma** | 18 | 1.34 | 16.0 | 0.41 | 0.73 | 2.18 | 13 | 3.0 |
| *Pseudolachnostylis maprouneifolia* | 21 | 1.52 | 35.16 | 0.15 | 0.75 | 2.27 | 14 | 8.3 |
| *Combretum collinum** | 23 | 1.66 | 46.15 | 0.08 | 0.41 | 2.07 | 15 | 5.4 |
| *Julbernardia globiflora* | 16 | 1.16 | 15.38 | 0.18 | 0.91 | 2.07 | 516 | 10.6 |
| *Diplorhynchus condylocarpon** | 25 | 1.81 | 17.58 | 0.04 | 0.20 | 2.01 | 16 | 4.2 |
| *Euphorbia matabelensis* | 22 | 1.59 | 17.58 | 0.02 | 0.01 | 1.60 | 17 | 3.1 |
| *Ochna pulchra* | 20 | 1.45 | 35.16 | 0.08 | 0.41 | 1.86 | 18 | 5.8 |
| *Croton gratissimus* | 15 | 1.08 | 3.30 | 0.07 | 0.35 | 1.43 | 19 | 6.7 |
| *Pterocarpus angolensis** | 13 | 1.22 | 9.51 | 0.67 | 0.35 | 1.31 | 20 | 5.0 |
| *Vangueriopsis lanciflora* | 14 | 1.01 | 1.02 | 0.02 | 0.01 | 1.02 | 21 | 3.6 |
| *Afzelia quanzensis** | 6 | 1.00 | 1.00 | 0.20 | 0.1 | 1.01 | 22 | 3.0 |

*Commonly harvested species

distribution of selected commonly harvested species was analysed individually to determine the status of populations of the individual species (Figure 2).

The commonly harvested individual species indicated a variable set of density distributions, including a reversed J-shaped curve (*Colophospermum mopane,Combretum collinum, Brachystegia spiciformis* and *Terminalia sericea*), a poorly defined bell shaped curve(*Pterocarpus angolensis and Commiphora mossambicensis*), a right tailed bell-shaped curve (*Baikiaea plurijuga, Kirkia acuminata, Guibourtia coleosperma, Afzelia quanzensis, Erythrophleum africanum* and *Commiphora angolensis*) and a truncated curve (*Diplorhynchus condylocarpon and Bauhinia petersiana*).

About 94% of stems per hectare for all species are below 27 cm diameter (size class 6) at breast height and 84% are below 12 cm (size class 3) (Figure 1). The data revealed very low numbers of trees in the larger size classes. Only 2% or 41 stems/ha are above 27 cm dbh (Figure 2).



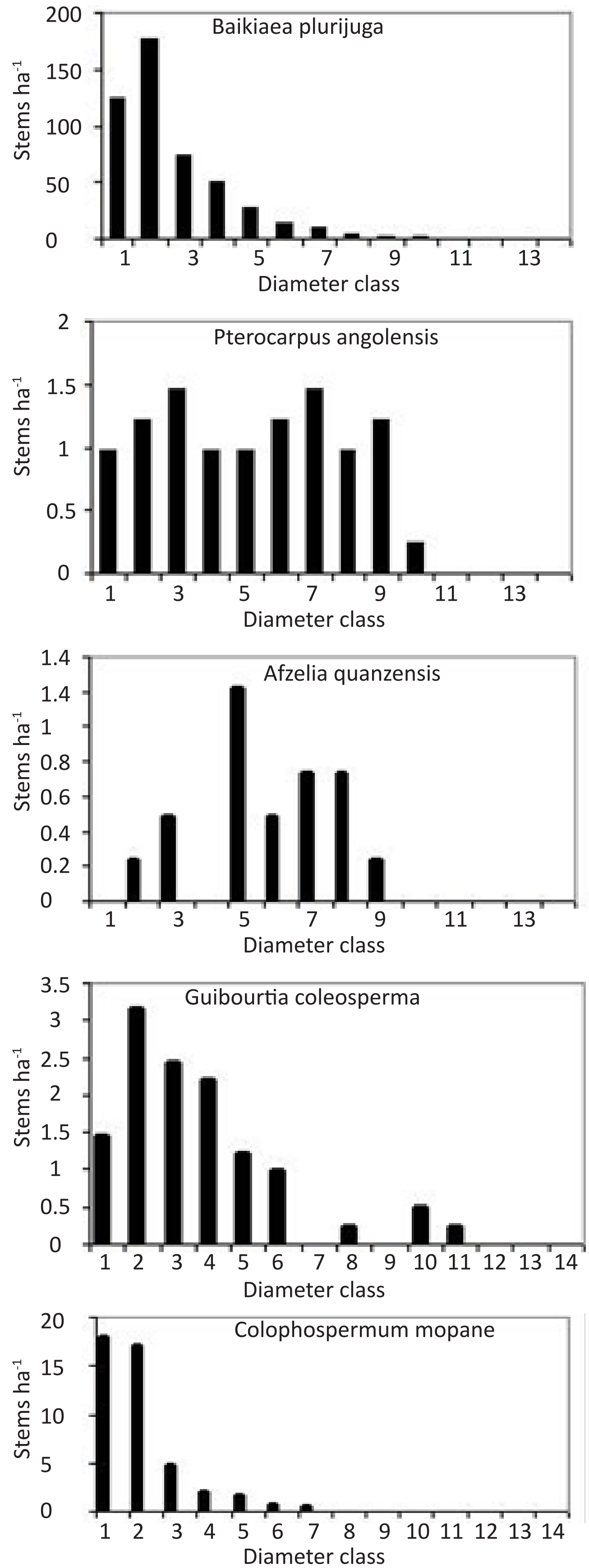

1: 2 – 6.9 cm; 2: 7 – 11.9 cm; 3: 12 – 16.9 cm; 4:17 –21.9 cm; 5: 22 – 26.9 cm; 6: 27 – 31.9 cm; 7: 32 –36.9 cm; 8: 37 – 41.9 cm; 9: 42 – 46.9 cm; 10: 47 – 51.9 cm; 11: 52 –56.9 cm; 12: 57 – 61.9 cm; 13: 62 – 66.9 cm; and 14: 67 cm and above

Figure 1: Stem diameter distribution of stems of all species encountered.Diameter class limits

Species with a tendency of multi-stemming e.g. *Bauhinia petersiana* have a narrow range of size classes. Another species with a narrow range of size classes is *Diplorhynchus condylocarpon*. All species except *Baikiaea plurijuga, Brachystegia spiciformis, Colophospermum mopane,* and *Bauhinia petersiana* are represented by less than 12 stems/ha in the available size classes (Figure 2). Some size classes of *Guibourtia coleosperma, Afzelia quanzensis, Commiphora angolensis* and *Terminalia sericea* are not represented by any individuals at all.

## 4. Discussion

A total of 75 woody species were recorded in Fuller Forest. Species composition in the forest appears superficially uniform, suggesting a broad similarity in key environmental

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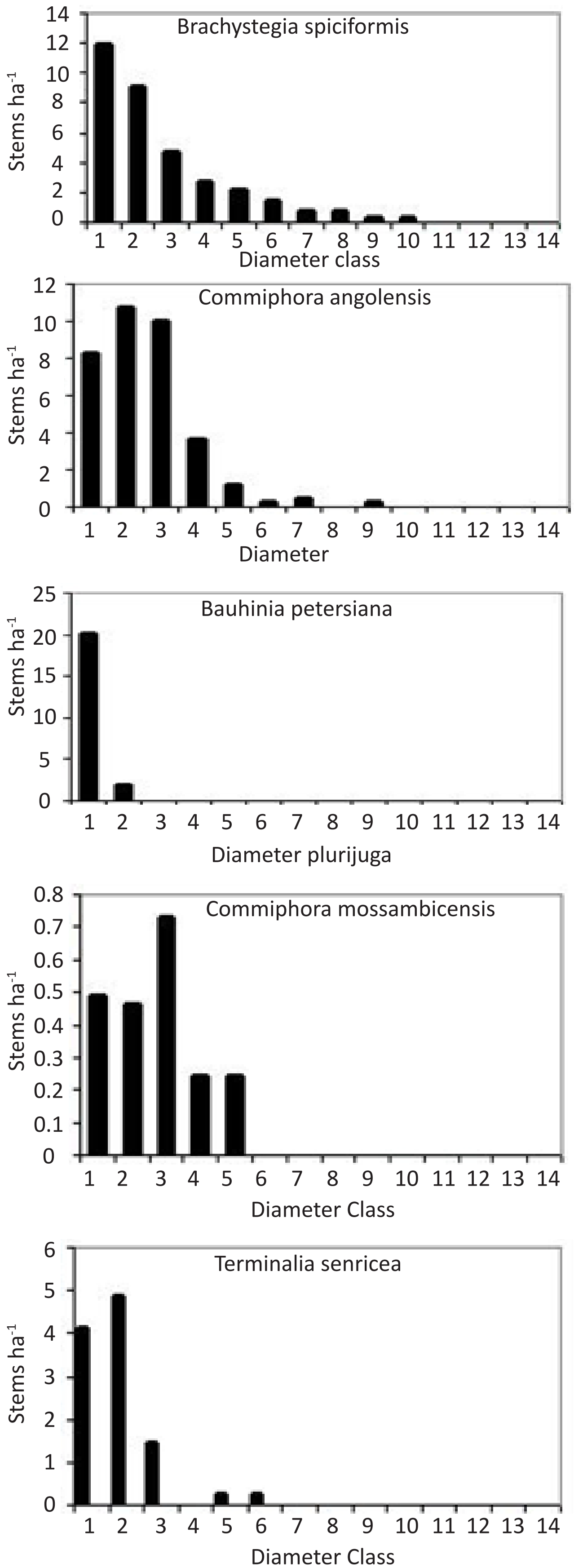


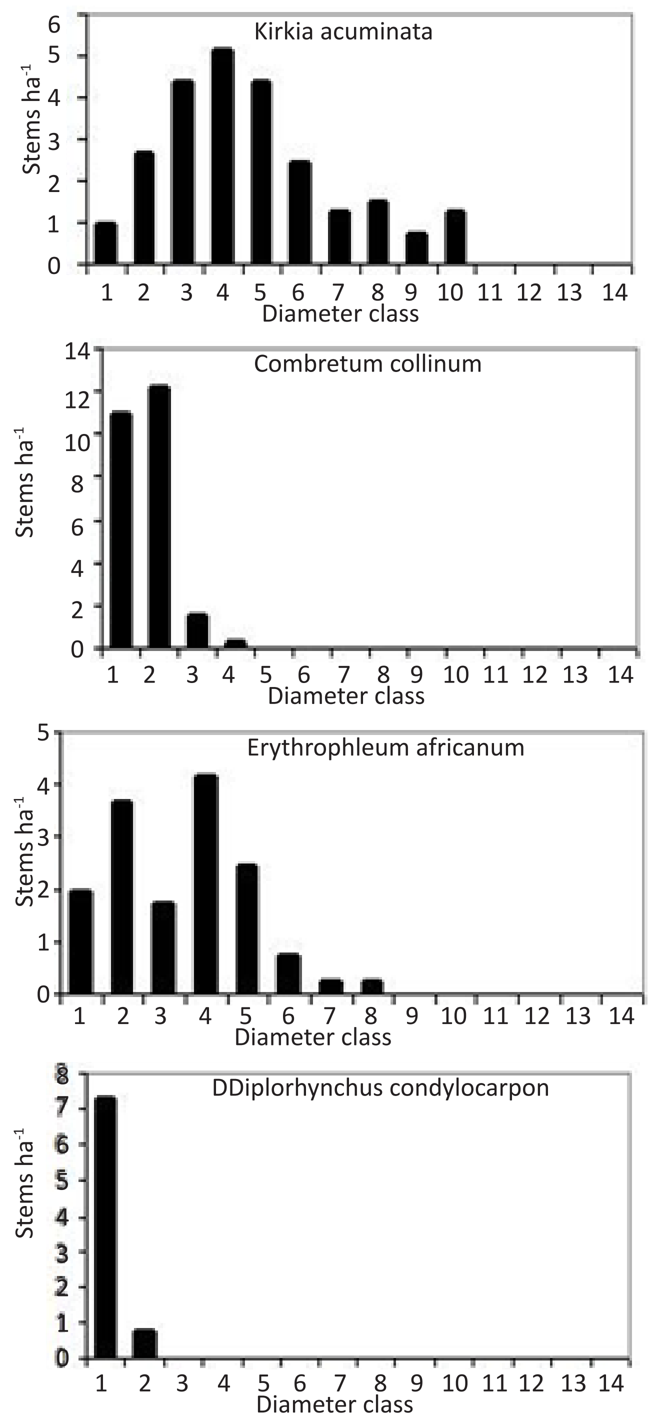


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Figure 2: The variation in population structure of commonly harveste harvested woody species

conditions. As such, the forest appears to be completely dominated by *Baikiaea plurijuga*. However, differences in species composition appear to be apparent at a local scale.

The determinants of species composition at the local scale over the predominantly extensive Kalahari Sand require further exploration. Intuitively the determinants appear to involve edaphic factors such as soil moisture, nutrients and depth (Astle 1969; Campbell *et al.* 1988), fire (Lawton 1978; Kikula 1986), wildlife impacts (Anderson and Walker 1974; Guy 1989), and past and present uses (Chidumayo 1987). *Baikiaea plurijuga* is dominant and typically found on deep sands (Calvert 1986b; Childes and Walker 1987), where its long roots enables access to deep aquifers which are important sources of water and nutrients in the permeable and infertile sands (Nyamapfene 1991). *Brachystegia spiciformis* invades Kalahari Sand where the soils become gravely and deep roots are not as important a competitive advantage (Calvert 1986b). *Kirkia acuminata* is more dominant on rocky areas of shallow soils. *Colophospermum mopane* occurs in depressions characterised by seasonal water inundation. Calvert (1986) notes *Terminalia sericea* as an indicator of deep sands, but Childes and Walker (1987) found that relative to *Baikiaea plurijuga* it was found at sites with poor drainage, which accords with the species distribution in the present study site.

The recorded number of species in Fuller Forest is comparable with results obtained from another protected forest located on Kalahari Sand. Mudekwe (2002) recorded 55 species in Mafungabusi Forest in the Midlands Province. Mafungabusi Forest has similar growth conditions as Fuller Forest. This similarity in number of species is probably due to the uniformity in topography and soil physical and chemical properties of the dominant Kalahari Sand. In both forests there is little variation in altitude and there are little non-descript drainage systems that would normally form niche habitats for a more diverse species composition.

Woody species that currently are not normally preferred for subsistence uses, *Bauhinia petersiana* and *Commiphora mollis,* are more abundant in terms of numbers per hectare and occur more frequently in the forest than those preferred for firewood, construction poles and wood for carving (Table 1). It appears *Bauhinia petersiana* and *Commiphora mollis* have managed to compete successfully with the more preferred species and these two species now dominate several parts of the forest. In the past the development of these two species was checked by the trampling and feeding actions of large herds of elephants and buffalo (Calvert 1986). In the recent past human disturbances seem to have resulted in the migration of these wildlife species from Fuller Forest.

Low abundance of the commonly harvested species is a concern for sustainable resource use. Forest users raised the issue during discussion sessions. Specifically, curio carvers and harvesters of construction poles were concerned that the increasing low abundance of preferred species where affecting their trade and the replacement of homestead structures respectively. Composition and tree density of favoured species could be improved through a better understanding of the silvicultural characteristics of individual species including their methods of and requirements for natural regeneration and how the species respond to varying intensities and frequencies of harvesting, grazing, browsing and fire (see for example Obiri and Lawes 2000, Bond and Rathogwa 2000, and Geldenhuys 2005). Presently, little is known of the silvicultural characteristics of the commonly harvested species. An adaptive management approach involving the local users is required where sustainable resource use can be matched to available resources through simple ecological monitoring of for example, species composition and tree density in order to provide important information needed to plan for resource utilisation and management. It will be useful to use ecological assessment indicators that the local users could easily understand and use. This would enable the users to measure changes in the status of the resources and take appropriate decisions to adjust the harvesting rates.

The stem diameter distributions of the selected and commonly harvested tree species in Fuller Forest show how the different species vary in their population demographics across the forest (Figure 2). The majority of the selected commonly harvested species had on average 6 size classes i.e. of trees up to 31 cm dbh. This seems to indicate that the forest has degenerated into a secondary forest dominated by small size stems for most species. In an inventory conducted 20 years ago the average dbh of Baikiaea plurijuga, Pterocarpus angolensis, Afzelia quanzensis and Burkea African was 47 cm (Judge 1975) Five species, *Diplorhynchus condylocarpon, Commiphora mocambicensis,Bauhinia petersiana* and *Terminalia sericea* had at most three size classes i.e. of trees up to 16 cm dbh. Except for *Terminalia sericea* the other three species are generally sub-canopy species and it is expected that they would only cover the smaller size classes. This means that harvesters have to concentrate all their harvesting within a small range of size classes in these species. For example, it was found that firewood harvesters prefer to cut trees between 4 cm and 16 cm dbh for the product. Depending on harvesting pressure, unplanned harvesting in these size classes may lead to decreased numbers of individuals in populations of target species. In the long-term the heavily affected size classes may eventually lose all individuals if remedial regeneration strategies are not put in place.

The density curves of the commonly harvested species were quite dissimilar. The wide range of density curves appears to be a reflection of disturbance factors (harvesting, fire, drought, browsing) (Shackleton 1993b) in the target species although Geldenhuys (pers. comm.) argues that the variation in the range could have been narrowed if density curves were analysed based on site conditions and harvesting histories. The Geldenhuys argument agrees with the findings of Rao *et al.* (1990), who reported a decreased range of curve types in disturbed sites.

Of the selected commonly harvested species *Baikiaea plurijuga*, *Colophospermum mopane,* and *Brachystegia spiciformis* exhibited the inverse J-shaped diameter size class distribution profiles. This characteristic size class structure is generally indicative of stable and expanding populations (Geldenhuys 1993; Shackleton 1993b; Obiri and Lawes 2000). A higher abundance of individuals in smaller size classes than the larger size classes and an almost constant reduction in the number of trees from one size class to the next, leading to an inverse J-shaped size class distribution, is generally regarded as an indicator of adequate regeneration and population maintenance (Lieberman 1996; Zagt and Werger 1998; Condit *et al.* 1998, 1999). Species with such population structure can be harvested sustainably.

*Pterocarpus angolensis* and *Afzelia quanzensis* have very few individuals in the forest to allow sensible deductions using the stem distribution curves. Despite their ability to resprout and coppice these species were not regenerating satisfactorily and their continued exploitation may lead to their extermination in the medium to long-term. The poor stocking of these two species might be ascribed to lack of fire (Geldenhuys 1977). This is contrary to Von Maltitz and Rathogwa (2000) who seem to point to the fact that growth of *Pterocarpus angolensis* is improved if fire is excluded particularly during the fire sensitive sufftrutex and pole stages. These conflicting findings on the ecology of *Pterocarpus angolensis* point to the need of further studies despite the amount of information presently available.

*Kirkia acuminata, Guibourtia coleosperma, and Erythrophleum africanum* all had bell-shaped profiles. It appears these species regenerate in cohorts' fashion. In fire adapted systems, like the Kalahari Sand teak forests the bell-shaped curve indicates fire intolerance (Calvert 1986). When fire is excluded the species regenerate and grow in such cohorts (Geldenhuys 1993). The present density profiles of these three species indicate that the intended complete exclusion of fire in the forest since 1925 (Judge 1975) has not been very successful. However, sustainability of these species in order that they provide required products on a sustained yield basis could be improved through targeted fire exclusion in sites where these species are dominant until such time when the trees reach 'escape height and diameter' where top kill and stem damage are no longer threats to the trees.

*Diplorhynchus condylocarpon, Commiphora mocambicensis* and *Bauhinia petersiana* exhibited relative linear decline in their populations. This linear decline is not a cause for concern as might be expected. Many woodland species exhibit diameter distribution profiles like those shown by these three species (Geldenhuys 2005). What is important is to guard against tree harvesting practices that would affect regeneration dynamics of the species e.g. non-selective cutting of seed bearing trees.

There is a marked absence of individuals of intermediate sizes in some size classes of populations of *Guibourtia coleosperma, Afzelia quanzensis, Pterocarpus angolensis* and *Terminalia sericea.* Although this was not empirically proved in this study, the absence of these individuals could be attributed to over-exploitation in the affected diameter classes although effects of other disturbance factors for example, fire and drought cannot be ruled out. In their studies Shackleton (1993b) and Obiri and Lawes (2000) reported absence of individuals in specific size classes as being due to harvesting pressure in these classes.

There is a marked reduction of individuals in the smallest size class in *Baikiaea plurijuga, Kirkia acuminata, Erythrophleum africanum,Commiphora angolensisGuibourtia coleosperma, Afzelia quanzensis, Pterocarpus angolensis*, *Combretum collinum* and *Terminalia sericea.* It appears that stems in the seedling and sapling growth stages experience periodic difficulties in successfully recruiting into the pole and intermediate stages. Bond and Rathogwa (2000) allude to the fact that fire and browsing frequency and intensity limit recruitment of seedlings and saplings into large size classes. Annual fires and grazing are prevalent in Fuller forest and it is hypothesised that these factors could be limiting recruitment from small to large size classes. However, this assumption requires that empirical studies be done so that key processes of how juveniles escape the disturbance factors to grow into larger size classes providing timber and poles are understood. If the bottlenecks are not removed or their amplitude reduced it can be predicted that populations of these species will decline in the future.

Foresters and forest ecologists have long used population structure data to study the status of woody species. Tree diameter size class distribution is an important stand variable that must be considered in the development of sustained use-management systems (Harper 1977; Walker *et al.* 1986; Geldenhuys 1993; Shackleton 1993b). Stand structure can be used as the basis for monitoring stand development when harvesting forest resources, as a tool in predicting woody species regeneration status and as an indicator of disturbance history (Lorimer 1980; Geldenhuys 1993, 2004, 2005; Shackleton 1993b). Tree diameter at breast height is the most commonly used variable in the analysis of woody plant structure although some studies have used tree height (Brown and Bredenkamp 2004). In savanna areas analyses of population structure is restricted to size class since age class data are unreliable because for most tree species growth rings are usually not directly related to age but rather reflect fluctuations in environmental conditions (Lilly 1977).

Studies to characterise size class distributions of woody species are scarce in the protected indigenous forests such as Fuller Forest. There is limited knowledge of the effect of management and use practices on the structure and stability of populations of target tree species yet changes in population structure may indicate impact of management and use. These changes if they occur should alert managers of situations of declining recruitment and development in populations of target species (Walker *et al*. 1986; Peters 1996).

The present status of populations of the commonly targeted woody species within Fuller Forest was determined. All species need to be protected from fire and grazing during the seedling and sapling development stages. There is need to pay attention to species where individuals were completely missing from some size classes as in the long run these species might not be able to sustain themselves. At present *Baikiaea plurijuga*, *Colophospermum mopane,Brachystegia spiciformis, Diplorhynchus condylocarpon, Commiphora mocambicensis* and *Bauhinia petersiana* appear to have relatively stable populations.

The situation exhibited by individual tree species populations of the commonly harvested species in Fuller Forest calls for better planning of harvesting and management practices to ensure that species populations are stable and self-sustaining. From the analysis of population structures of the target species it appears harvesting practices have had an impact on the populations although impact of other factors such as fire and grazing cannot be ruled out. Future management focus should be directed at achieving normal forest stands and reducing for example, situations where some target species have missing individuals in some size classes and situations where there is poor recruitment in the smallest size classes. Some of the species need silvicultural management to achieve a constant recruitment of stems in the smaller size classes, and recruitment to the next larger classes to allow for the minimum allowable harvest in each of the harvestable size classes.

As discussed, the most important processes in Fuller Forest are disturbances (harvesting, fire, grazing and browsing), and recovery from the disturbances through for example, seed regeneration, resprouting and coppicing. For this forest and any other forest the disturbance and recovery processes should form the basis of silviculture and management practices. The focus should be on recording observations of what happens to forest stands and individual trees after any disturbance e.g. subsistence harvesting. This aspect should form part of participatory monitoring, evaluation and adjustment of use practices. In situations where resources cannot recover from harvesting impacts, alternative resources or products have to be developed.

## 5. Conclusion

The literature review in this study indicates that there is scant, mostly anecdotal information on the ecological sustainability of harvesting forest products in protected forests. An analysis of the woody forest resource base indicates that populations of some of the target species are not stable. It is likely that use practices accompanied by grazing, fire, browsing, climatic and edaphic factors, have had some impact on populations of the target species. Taken together, these factors have had overall detrimental effect on species composition, plant regeneration and densities of the target species. There is also evidence from published literature for other parts of the world that management and use practices of forest resources may be leading to overall forest degradation.

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