

DEMOGRAPHY AND DYNAMICS OF COMMONLY HARVESTED WOODY SPECIES IN A PROTECTED INDIGENOUS FOREST IN ZIMBABWE

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Abstract

Intense pressure on forest resources in demarcated indigenous forests in North Western Zimbabwe has stimulated rethinking on what forests should be for and by whom they should be managed. In the recent past the government of Zimbabwe has created a process of reassessment of forest management in light of poor resources available to the government forestry agency; inadequate assertion of control over subsistence use of the forests and the perceived pernicious degradation of the forest resources by rural communities living around the forest.

This study aimed at contribution to this rethinking process. The study explored and reviewed the contribution that forests make to rural welfare. Existing use patterns were examined including types of goods derived from the study area, the diversity of forest users and their interests, conflicts and cooperation, management interventions and impacts of harvesting the woody component.

Woody resources were the most harvested from the forest, particularly for construction purposes, fencing, commercial timber, fuelwood, wood for implements and curios. The size class distributions of the twelve commonly harvested woody species were determined. Most of the size class profiles indicated that the species populations were not stable, indicating impacts of past and present management and utilisation practises. Harvesting practises reduced the absolute densities and altered the size class profiles of most woody species. It is doubtful whether in future the woody community would be able to supply adequate goods required on a sustainable basis.

1. Introduction

Throughout the developing countries a high percentage of people in rural areas depend on a vast array of timber and non-timber forest products (Obiri & Lawes, 2000). Understanding the dynamics around these forest resources is central in achieving sustainable use-management and overall conservation of indigenous forests and woodlands. In recent times there has been an increased awareness that use of forest products forms a substantial part of the rural livelihoods of many people living in and outside protected forests and that sustainable management of these forest products can enhance people's welfare while maintaining the forest ecosystems (Panayotou & Ashton, 1992; Peters, 1996).

Often there is a contradiction in forest resource use and their maintenance. For example, harvesting bark for medicinal purposes or wood for carving or harvesting of wild fruits sometimes involves destructive harvesting practices that impact on the plant populations being harvested (Peters, 1996; Obiri & Lawes, 2000). In these circumstances highly sought plant species may fail to sustain harvesting pressure and eventually undergo losses in population numbers (Cunningham, 1988; Redford, 1992).

Characterisation of diameter size class distribution of harvested woody species is a useful tool for monitoring forest stands in which harvesting is taking place (Geldenhuys, 1993). Size class distribution profiles can also be used to project population trends of species being harvested (Shackleton, 1993) and also facilitate inferences regarding the stability the harvested populations.

These kinds of studies are rare in protected indigenous forests in Zimbabwe. Before and after they had been gazetted these protected indigenous forests have been under extensive harvesting of woody plants used for subsistence purposes. Forest managers have little empirical knowledge of the effect of harvesting for subsistence on the structure and stability of populations being harvested. Often changes in tree population structure takes place before changes in species composition making population structure a useful indicator of use impact on woody species populations (Lorimer, 1980; Pellew, 1983; Walker 1986).

By definition tree population structure is the expression of the frequency distribution of variously sized trees in a given forest stand (Geldenhuys, 1993; Peters, 1996). Diameter at breast height is the most commonly used size variable in the analysis of that structure although some other studies have used height (e.g. Brown & Bredenkamp, 2004).

This study sought to describe the size distributions of the commonly harvested tree species in Fuller protected indigenous forest. Key questions that were addressed were:

1. What is the pattern of distribution and structure of populations of the commonly harvested woody species?
2. Are populations of the commonly harvested woody species in a stable state?
3. How has subsistence use impacted on the structure of the harvested woody species?

2. Study area

Fuller Forest Reserve lies between 18°08'31" South and 25°56'16" East. The forest reserve covers approximately 23 300 ha. The dominant climatic characteristic in and around Fuller Forest is a short and erratic rainfall season from mid-November to mid-March. Mean annual rainfall is 550 mm. The low and erratic rainfall phenomenon comprises a major constraint to dry land crop production. Mean annual temperature in is approximately 21.5°C. Mean monthly temperatures in the hot and cold months are about 30°C and 17°C respectively.

Mafungabusi forest is 82 100 hectares in extent. Mean annual rainfall is 650 mm and the mean annual temperature is 20°C. The main rain season is from November to March with considerable variability from year to year.

The forests were gazetted for conservation purposes and for the production of commercial timber. Kalahari sands cover the bulk of Fuller and Mafungabusi forests and the surrounding areas. The sands comprise deep unconsolidated tertiary sands of aeolian origin (Nyamapfene, 1991). The Kalahari sands are strongly uniform physically and chemically. The soils are well drained and deep and have medium grained sands (Anderson *et al.*, 1993). The sands are extremely infertile (Nyamapfene, 1991) and this severely limits the potential for crop production. Both forests perform a number of ecological and socio-economic functions that include protection of the fragile Kalahari sands, watershed protection, provision of wildlife habitat, and as a source of timber and non-timber forest products.

The Kalahari sands support a predominantly *Baikiaea plurijuga* forest type. The vegetation shows a distinct catenary pattern with *Baikiaea* on the ridge, while *Burkea*, *Terminalia*, *Combretum* mixed scrub and occasionally *Colophospermum mopane* are found on seep lines and in vleis. Vegetation of the Kalahari sands has been described by Fanshawe and Savory (1964), Childes and Walker (1987), Wood (1986) and Huckabay (1986).

3. Methods

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 overlays. Concentric circular sample plots with a radius of 12m (452m²) and of 2m (12.6m²) for tallying the woody component and regeneration respectively, were used. Altogether 91 plots were sampled. Within each 12m – radius plot the following parameters were recorded:

1. The diameter at breast height of each woody stem for stems equal to or greater than 2cm. The minimum of 2cm stem diameter was based on the observation that such material was used extensively in the construction of small livestock pens and granaries. For coppices, each stem was measured separately and averaged to obtain an estimated diameter of the main rootstock. A minimum diameter of 2cm 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 2m – radius plots regeneration by species was tallied. Stems less than 2cm 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. Such shrubs are inherently multi-stemmed and the stems were generally less than 2cm in diameter.

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

4. Results

A total of 75 woody species were recorded in the forest. Descriptive statistics of the 12 commonly harvested species are shown in Table 1 showing how commonly a species occurs across the entire forest, the total number of individuals of a particular species and the total amount of forest area occupied by the species. The most dominant and common tree is *Baikiaea plurijuga* with an absolute density of 483 trees/hectare, a relative density of 34.9% and frequency of 78.02%. There is considerable variation in stem absolute density of the commonly harvested species ranging from 1 to 483 stems/hectare.

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 *Guibourtia coleosperma* (18 stems/ha). Species favoured for construction poles had absolute densities of *Commiphora angolensis* (86 stems/ha), *Kirkia acuminata* (53 stems/ha), *Colophospermum mopane* (44 stems/ha), *Erythrophleum africanum* (41 stems/ha), *Diplorhynchus condylocarpon* (25 stems/ha), and *Terminalia sericea* (24 stems/ha). For species favoured for woodcarving the absolute densities were *Pterocarpus angolensis* (13 stems/ha) and *Azelia quanzensis* (6 stems/ha).

There are four woodland types present in Fuller forest. The density plots of the commonly harvested woody species across the four woodland types were analysed to determine the status of their populations. The density plot of all stems encountered in the four woodland types displayed a negative exponential diameter size class distribution profile indicative of a stable woody community in the forest (Figure 1).

Table 1. Demography of commonly harvested woody species

Species	Stems / ha	Relative density	Frequency	Relative frequency	Basal area/ha (m ²)	Relative dominance	Importance value
<i>Baikiaea plurijuga</i>	483	34.90	78.02	14.88	7.74	39.21	88.99
<i>Commiphora angolensis</i>	86	6.21	26.71	5.09	1.03	5.22	16.52
<i>Kirkia acuminata</i>	53	3.83	56.04	10.68	2.48	12.56	27.07
<i>Colophospermum mopane</i>	44	3.17	12.09	2.30	0.43	2.18	7.65
<i>Erythrophleum africanum</i>	41	2.96	50.55	9.64	0.90	4.55	17.15
<i>Brachystegia spiciformis</i>	33	2.38	32.97	6.29	0.67	3.39	12.06
<i>Diplorhynchus condylocarpon</i>	25	1.81	17.58	3.35	0.04	0.20	5.36
<i>Terminalia sericea</i>	24	1.79	35.16	6.70	0.23	1.17	9.66
<i>Combretum collinum</i>	23	1.66	46.15	8.80	0.08	0.41	10.87
<i>Guibourtia coleosperma</i>	18						
<i>Pterocarpus angolensis</i>	13						
<i>Azelia quanzensis</i>	6						

In the dominant *Baikiaea plurijuga* woodland density plots of *Baikiaea plurijuga*, *Guibourtia coleosperma*, *Combretum collinum*, *Brachystegia spiciformis* and *Commiphora angolensis* exhibited inverse J-shaped diameter size class distribution profiles (Figure 2) characteristic of stable populations. In the same woodland *Pterocarpus* and *Azelia* species had variable size class distribution profiles that were difficult to interpret due to the low numbers of individuals in any of the size classes. Two species *Kirkia acuminata* and *Erythrophleum africanum* had bell shaped profiles. *Colophospermum mopane* that formed an almost pure stand displayed the standard inverse J-shaped population structure as well as *Brachystegia spiciformis* that was dominant in the *Brachystegia* woodland. *Diplorhynchus condylocarpon* had two size classes only in all four woodland types while *Combretum collinum* and *Terminalia sericea* had four and three size classes respectively. Except for *Baikiaea plurijuga* the rest of the preferred species had less than twenty individuals in the available size classes. Size classes of some of the species were not represented by any individuals particularly *Azelia quanzensis*, *Guibourtia coleosperma*, *Combretum collinum* and *Terminalia sericea*. In general almost all populations had a couple or no individuals in the largest size classes. All species have reduced numbers of individuals in the lowest 2cm to 6.9 cm diameter class in comparison with the next size class.

5. Discussion

The composition of the woody vegetation in Fuller appears superficially to be relatively uniform over the whole forest, suggesting a broad similarity in key environmental conditions. The forest appears to be completely dominated by *Baikiaea plurijuga*. This apparent uniformity in appearance is due in part to the remarkably similar physiognomy of this dominant species. The dominance of the genus *Baikiaea plurijuga* makes Fuller Forest floristically distinct from other savannah woodland formations in the region. The genus is not found outside the Kalahari Sand ecosystem (Brummitt, 1986).

Differences in species composition are 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, 1986b), wildlife impacts (Anderson & Walker, 1974; Guy, 1989), past and present uses (Chidumayo, 1987). The total number of recorded woody species (75 species) compares well with those found in a similar protected indigenous forest where 64 woody species were recorded (Mudekwe, 2002). Out of the recorded number of species only twelve are highly preferred for various subsistence purposes such as the provision of wood for energy, wood for carving and construction poles.

Shackleton (1993), Lowore *et al.*, (1995b) and Abbot (1996) established that harvesters exercised preferences and selection for desired attributes when harvesting trees. The low abundance of some of the preferred species in Fuller Forest could be inherent in the life histories of the specific species. However, it appears the commonly harvested species in Fuller, particularly, *Azelia quanzensis* and *Pterocarpus angolensis* have been under immense subsistence and commercial harvesting pressure for a long time in the past and little attention has been paid to silvicultural practices that would increase their density.

The low density of stems per hectare for the majority of the favoured species in Fuller Forest means that harvesters will invest in considerable time in search of the preferred species and the preferred sizes of trees. Given that livelihood strategies for the rural households need to be diverse, less time could be available for other important strategies while household members spend more time searching for wood material required in the household. The illustrated low densities of some commonly used species in Fuller Forest need to be improved by initiating and encouraging enrichment planting and improving conditions for natural regeneration to improve stand stocking (Obiri & Lawes, 2000). These initiatives require collaboration between the forestry Commission and the local communities in which management approaches would involve mixing local silviculture and ecology knowledge and conventional forest management practices.

The mix of species in Fuller Forest makes it difficult to have a single management practice that would benefit all the species. The different species behave differently to various environmental and disturbance factors, for example harvesting, fire and grazing. In order to achieve sustainable management of most commonly harvested tree species their silviculture and ecology must be studied. Peters (1996) and Geldenhuys (2005) give some useful guidelines on management approaches of woody species in natural forests and woodlands.

While there are considerable initiatives in support of use and commercialisation of the woody component in forests for the improvement of local livelihoods, it appears little focus is being accorded to suitable approaches for the sustainable management of the commonly harvested and multi-purpose species (Ford Foundation, 1998; Shackleton *et al.*, 2000). For example, fire appears to be one of the determinants of species composition in Fuller Forest. Despite annual complete fire protection programmes in the forest, the forest experiences anthropogenic fires every year (Forestry Commission, 1994). A cue on managing woody

species under different fire regimes can be taken from Calvert's review of fire studies in Gwaai Forest (Calvert, 1993). In burning trials in the *Baikiaea* woodland, Gwaai Forest, Calvert (1993) observed that fire (13 years data analysis) results in loss of trees of various species and caused a trend from single to group rootstocks and multi-stems. Burning at different times of the year (between May and late September) also had different impacts on structure and species composition.

In this trial fire sensitive species were observed to be *Baphia massaiensis*, *Pseudolachnostylis maprouneifolia*, *Commiphora mossambicensis*, *Baikiaea plurijuga* and *Guibourtia coleosperma*. The fire tolerant species included *Burkea africana*, taller (above 3 m) and large diameter stems of *Pterocarpus angolensis*, *Erythrophleum africanum*, *Diplorhynchus condylocarpon*, *Terminalia sericea*, *Ochna pulchra*, *Bauhinia petersiana* and *Combretum zeyheri*. An important conclusion made was that annual fire has a depressive effect on *Baikiaea* woodland in terms of a shift in species composition towards non-timber species and from single to multi-stemmed rootstocks. These insights could be used to promote the development of preferred woody species in the protected indigenous forests such as Fuller.

Foresters and ecologists have long used population structure data to study the status of forest tree species. Stem diameter distributions provide useful information on the structure, stability and instability of tree species in a particular forest (Harper, 1977; Walker *et al.*, 1986, Shackleton, 1993; Geldenhuys, 1993). The stem diameter distributions of different tree communities, and of species across different communities provided useful information to interpret the dynamics of the communities and the species. The stem diameter distributions of the commonly harvested species in the different woodland types in Fuller Forest show how the different species vary in population demography between the different woodland types.

For most species recorded in the forest the shapes of the density curves were quite dissimilar displaying a range of distributions. For example, *Baikiaea plurijuga*, *Colophospermum mopane*, *Combretum collinum* and *Brachystegia spiciformis* exhibited the standard reversed J-profile, *Pterocarpus angolensis*, *Kirkia acuminata* and *Erythrophleum africanum* where characterised by bell-shaped curves while the rest of the preferred species exhibited variable sets of density distributions. This range of density curves could be a reflection of disturbance factors (Shackleton, 1993) and this is contrary to the findings of Rao *et al.*, (1990), who reported a decreased range of curve types in disturbed sites. The characteristic inverse J-shaped size class structure is indicative of stable and expanding populations (Obiri & Lawes, 2000: Shackleton, 1993; Geldenhuys, 1993). 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 regarded as an indicator of adequate regeneration and population maintenance (Condit *et al.*, 1998; Condit *et al.*, 1999; Lieberman, 1996; Zagt & Werger, 1998). Ideally this is the type of structure that one strives to maintain in natural populations of woody communities.

In Fuller forest harvesters and forest managers have to be wary of those species whose populations are unstable e.g. *Pterocarpus angolensis*, *Azelia quanzensis* and *Erythrophleum africanum*. These species for example have bell-shaped size distribution profiles indicative of species that regenerate and develop in cohorts after a window of suitable conditions for regeneration appear.

The reduction of the range of size classes present for most of the species is a reason for concern and has management implications. There might be need to reduce the harvesting pressure in the medium to long term so that regeneration establishes at regular intervals a situation that might lead to standard size class distributions of the unstable species.

The commonly harvested species have experienced a decrease in absolute density in the forest. Particularly affected species are *Azelia quanzensis* and *Pterocarpus angolensis*. These species are not only favoured for subsistence uses but they are also important timber species and have been commercially over-exploited in the past. For these favoured species changes in size class structure and reduction in absolute density may eventually lead to reduced species richness.

Subsistence uses as well as commercial exploitation have had some impact on populations of commonly harvested species. This is exhibited through a reduction in the number of size classes available and a reduction in the proportion of the population in some size classes. It is also hypothesised that subsistence use and commercial exploitation has resulted in species-specific reduction in absolute density and density in preferred size classes.

6. Conclusion

The combined information of community composition and diameter distributions gives the best initial understanding of the status and dynamics of woody species in Fuller Forest. Management activities that are based on this initial understanding should provide for conditions that improve the sustainability of the harvested species populations. This study has indicated that stability of woody populations may be difficult to attain under environments typified by subsistence and commercial harvesting. It is also difficult to infer stability of woody species populations from diameter size class distributions if absolute densities are

declining due to various disturbance factors. The study has given insights of the potential effects of tree harvesting on the structure and stability of tree populations in Fuller protected indigenous forest. This information can be used for the sustainable management of these species for the production of timber and non-timber products. Such studies must be encouraged in Zimbabwe's protected forests so that the gap between use and maintenance of tree populations being harvested is narrowed.

References

- ABBOT, J.I.O. (1996). *Rural subsistence and protected areas: community use of the miombo woodlands of Lake Malawi National Park*. Ph.D. thesis, University College, University of London.
- ASTLE, W.L. (1969). The vegetation and soils of Chishinga Ranch, Luapula Province, Zambia. *Kirkia* 7: 73-102.
- ANDERSON, G.D. & WALKER, B.H. (1974). Vegetation composition and elephant damage in the Sengwa Wildlife Research Area, Rhodesia. *Journal of the Southern African Wildlife Management Association* 4: 1-14.
- ANDERSON, I.P., BRINN, P.J., MOYO, M. & NYAMWANZA, B. (1993). *Physical resource inventory of the communal lands of Zimbabwe – an overview*. NRI Bulletin 60, Natural Resources Institute, Chatham, UK.
- BROWN, L.R. & BREDENKAMP, G.J. (2004). The use of structural species size class in the description of the woody vegetation of a nature reserve. *African Journal of Ecology* 42: 252-269.
- BRUMMITT, R.K. (1986). A taxonomic perspective of the genus *Baikiaea*. In: PEARCE, G.D. (ed.). *The Zambezi Teak Forests. Proceedings of the first international conference on the teak forests of southern Africa*. March 1984 Livingstone, Zambia. pp. 61-73.
- CALVERT, G.M. (1993). Indigenous species trials established upon the Kalahari Sands of north-western Matabeleland between 1926 and 1989: a summary. In: PEARCE, G.D. & GUMBO, D.J. (eds.). *The Ecology and Management of Indigenous Forests in Southern Africa. Proceedings of an international symposium, 27-29 July 1992, Victoria Falls, Forestry Commission of Zimbabwe/SAREC*. pp. 168-181.
- CAMPBELL, B.M., SWIFT, M.J., HATTON, J. & FROST, P.G.H. (1988). Small-scale vegetation pattern and nutrient cycling in Miombo woodland. In: VERHOEVEN, J.T.A., HEIL, G.W. & WERGER, M.J.A. (eds.). *Vegetation Structure in Relation to Carbon and Nutrient Economy*, SPB Academic Publishing, The Hague. pp. 69-85.
- CHIDUMAYO, E.N. (1987). Woodland structure, destruction and conservation in the copperbelt area of Zambia. *Biological Conservation* 40: 89-100.
- CHIDUMAYO, E.N. (1992a). Seedling ecology of the miombo woodland tree, *Julbernardia globiflora*. *Vegetatio* 103: 51-58.
- CHIDUMAYO, E.N. (1992b). Effects of shoot mortality on the early development of *Azelia quanzensis* seedlings. *Journal of Applied Ecology* 29: 14-20.
- CHILDES, S.L. & WALKER, B.H. (1987). Ecology and dynamics of the woody vegetation on the Kalahari Sands in Hwange National Park, Zimbabwe, *Vegetatio* 72: 111-128.
- CONDIT, R., SUKUMAR, R., HUBBELL, S.P. & FOSTER, R.B. (1998). Predicting trends from size distributions – A direct test in a tropical tree community. *American Naturalist* 152(4): 494-609.
- CONDIT, R., LOO DE LAO, S., LEIGH, E.G., FOSTER, R.B., SUKUMAR, R., MANOKARAN, N & HUBBELL, S.P. (1999). Assessing forest diversity from small plots: Calibration using species individual curves from 50 ha plots. In: DALLMEIER, F. & COMISKY J.A. (eds.). *Forest Biodiversity Research, Monitoring and Modelling: Conceptual Background and Old World Case Studies, Man and the Biosphere (MAB) Series, Volume 20*, UNESCO, Paris. pp. 247-68.
- CUNNINGHAM, A.B. (1988). *An investigation of the herbal medicine trade in Natal/KwaZulu*. Report No. 29. INR, Pietermaritzburg.
- FANSHAWE, D. B. & SAVORY, B. M. (1964). *Baikiaea plurijuga* dwarf shelf forests. *Kirkia* 4: 185-190.

- FORD FOUNDATION. (1998). *Forestry for Sustainable Rural Development: A review of Ford Foundation supported community forestry programmes in Asia*. Ford Foundation, New York.
- FORESTRY COMMISSION, (1994). Forest Resources Sharing Project: Mafungabusi demarcated forest reserve. Forestry Commission, Harare.
- GELDENHUYS, C.J. (1993). The use of diameter distributions in sustained-use management of forests: Examples from Southern Africa. In: G.D. PEARCE & D.J. GUMBO (eds.). *The Ecology and Management of Indigenous Forests in Southern Africa. Proceedings of an International Symposium, 27-29 July 1992, Victoria Falls*. pp. 154-167.
- GELDENHUYS, C.J. (1997). The effect of different regimes of annual burning on two woodland communities in Kavango. *Southern African Forestry Journal* 102:32-42.
- GUY, P.R. (1989). The influence of elephants and fire on a *Brachystegia-Julbernardia* woodland in Zimbabwe. *Journal of Tropical Ecology* 5: 215-226.
- HARPER, J.L. (1977). *Population Biology of Plants*. Academic Press, New York.
- HUCKABAY, J.D. (1986). The exploitation of Zambezi teak in Zambia. In: PEARCE, G.D. (ed.). *The Zambezi Teak Forests. Proceedings of the first international conference on the teak forests of southern Africa*. March 1984 Livingstone, Zambia. pp. 329-341.
- KIKULA, I.S. (1986). The influence of fire on the composition of Miombo woodland of Southwest Tanzania. *Oikos* 46: 317-324.
- LIEBERMAN, D. (1996). Demography of tropical tree seedlings: A review. In: SWAINE, M.D. (ed.). *The Ecology of Tropical Forest Tree Seedlings*, MAB Series, Volume 17. UNESCO, Paris. pp. 131-38.
- LAWTON, R.M. (1978). A study of the dynamic ecology of Zambian vegetation. *Journal of Ecology* 66: 175-198.
- LOWORE, J.D., COOTE, H.C., ABBOT, P.G., CHAPOLA, G.B. & MALEMBO, L.N. (1995). Community use and management of indigenous trees and forest products in Malawi. The case of four villages close to Chimaliro forest reserve. Report No. 93008, Forestry Research Institute of Malawi, Zomba.
- LORIMER, C.G. (1980). Age structure and diameter disturbance history of a southern Appalachian virgin forest. *Ecology* 61: 1169-1184.
- MUDEKWE, J. (2002). Adaptive co-management project: Mafungabusi forest reserve: Baseline study of the forest resources & collaborative monitoring mechanisms guidelines. Forest Research Centre, Forestry Commission, Harare.
- NYAMAPFENE, K. (1991). *The Soils of Zimbabwe*. Nehanda Publishers, Harare.
- OBIRI, J. & LAWES, M. (2000). The sustainable use of timber and non-timber products: A case study from Umzimvubu District, Pondoland, South Africa. In: SEYDACK, A.H.W., VERMEULEN, W.J. & VERMEULEN, C.(eds.). *Towards Sustainable Management Based on Scientific Understanding of Natural Forests and Woodlands. Proceedings of a Natural Forests and Savanna Woodlands Symposium II, 5-9 September 1999, DWAF, Knysna*.
- PANAYOTOU, T. & ASHTON, P. (1992). *Not by Timber Alone. Economics and Ecology of Sustainable Tropical Forests*. Island Press, Washington DC.
- PETERS C.M. (1996). Observations on the sustainable exploitation of non-timber forest products. An Ecologist's Perspective. In: RUIZ PEREZ, M. & ARNOLD, J.E.M. (eds.). *Current Issues in Non-timber Forest Products Research. Proceedings of the workshop 'Research on NTFP,' 28 August – 2 September 1995, Hot Springs, Zimbabwe*.
- RAO, P., BARIK, S.K., PANDEY, H.N. & TRIPATHI, R.S. (1990). Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. *Vegetatio* 88: 151-162.
- REDFORD, K.H. (1992). The empty forest. *Bioscience* 42: 412-422.
- SHACKLETON, C.M. (1993a). Demography and dynamics of the dominant woody species in a communal and protected area of the eastern Transvaal Lowveld. *South African Journal of Botany* 59(6): 569-574.
- SHACKLETON, C.M. (1993b). Fuelwood harvesting and sustainable utilisation in a communal grazing land and protected area of the eastern Transvaal Lowveld. *Biological Conservation* 63: 247 –254.

- SHACKLETON, S., SHACKLETON, C.M., NETSHILUVI, T., GEACH, B. & BALANCE, A. (2000). How valuable are our woodlands for sustainable rural livelihoods? Local-level valuation of woodland resources from three villages in South Africa. In: SEYDACK, A.H.W., VERMEULEN, W.J. & VERMEULEN, C. (eds). *Towards Sustainable Management Based on Scientific Understanding of Natural Forests and Woodlands. Proceedings: Natural Forests and Savanna Woodlands Symposium II*, 5-9 September 1999, DWAF, Knysna.
- WALKER, R.B., STONE, L., HENDERSON, L. & VERNEDE, M. (1986). Size structure analysis of the dominant trees in a South African savanna. *South African Journal of Botany* 52: 397-402.
- WOOD, A.P. (1986). Man's impact upon the Mukusi forests of Zambia, with special reference to Sesheke District. In: Pearce, G.D. (ed.). *The Zambezi Teak Forests. Proceedings of the first international conference on the teak forests of southern Africa*. March 1984, Livingstone. pp. 24-42.
- ZAGT, R.J., & WERGER, M.J.A. (1998). Community structure and the dynamics of primary species in tropical rainforest. In: Newbery, D.M., Prins, H.H.T. & Brown N.D. (eds.). *Dynamics of Tropical Communities. The 37th Symposium of the British Ecological Society*, Cambridge University, Blackwell Science, Oxford. pp.193-219.

Addendum

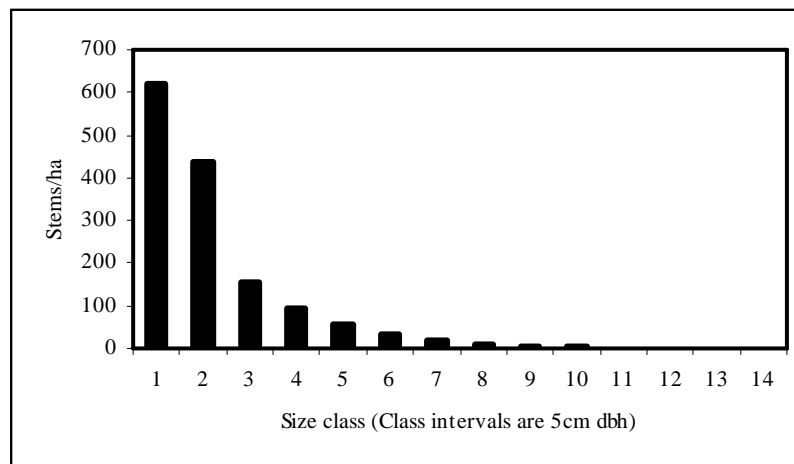


Figure 1. Stem diameter distribution of stems of all species encountered.

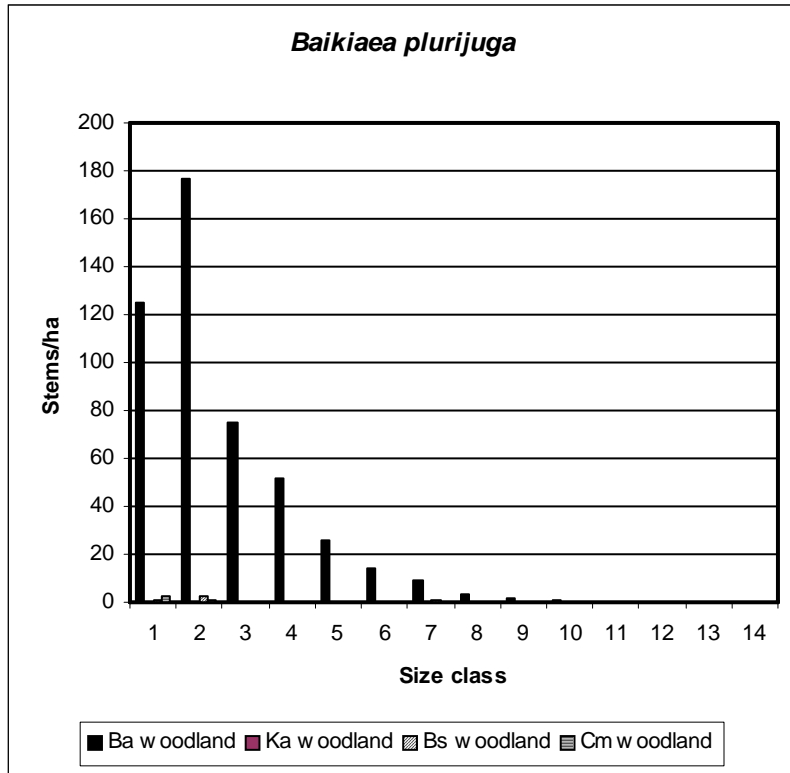


Figure 2(a).The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Baikiea plurijuga*.

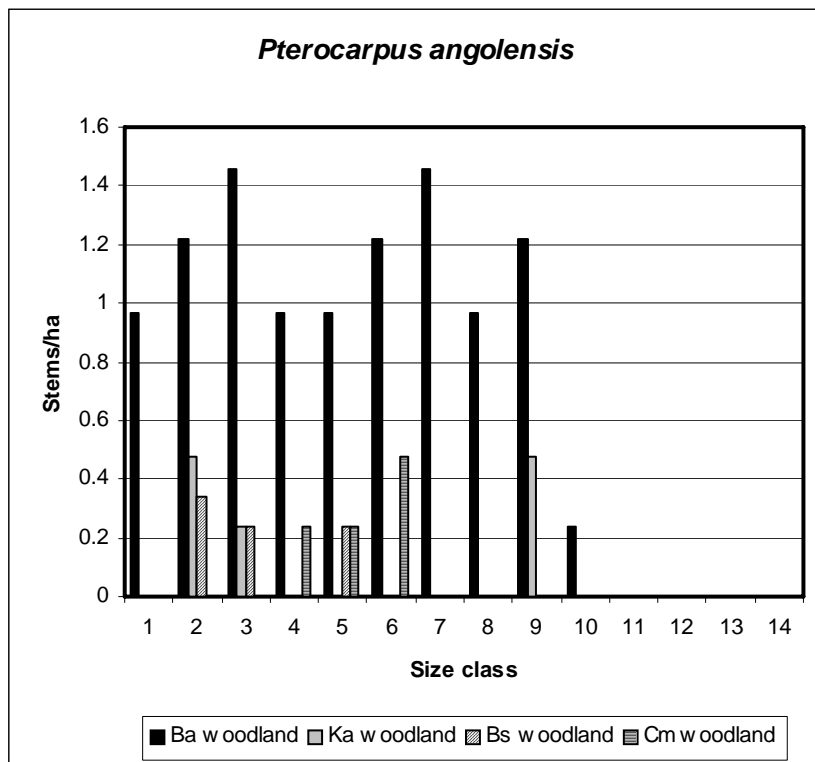


Figure 2(b) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Pterocarpus angolensis*.

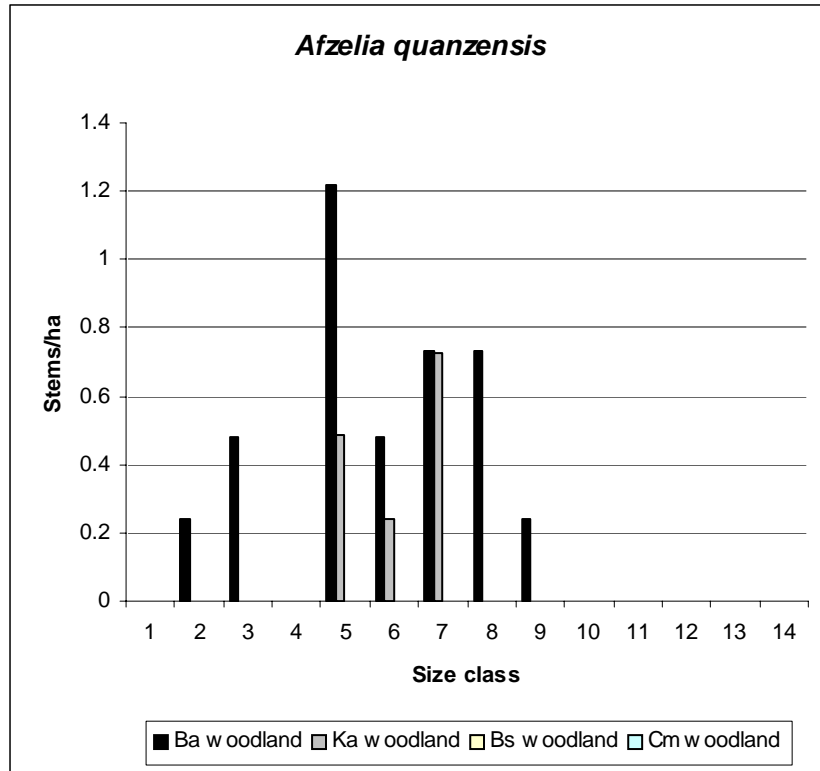


Figure 2(c) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Afzelia quanzensis*.

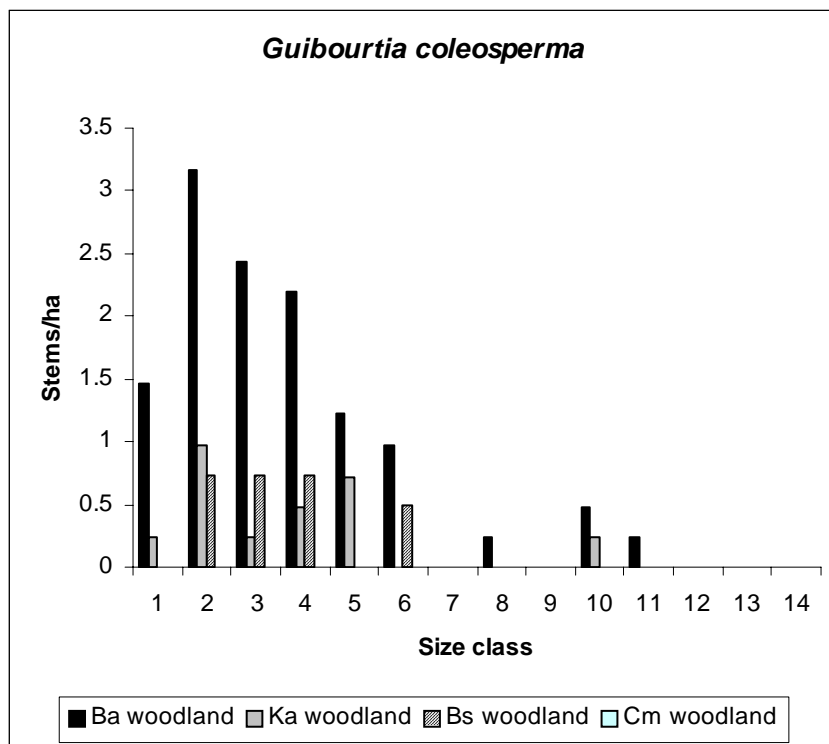


Figure 2(d) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Guibourtia coleosperma*.

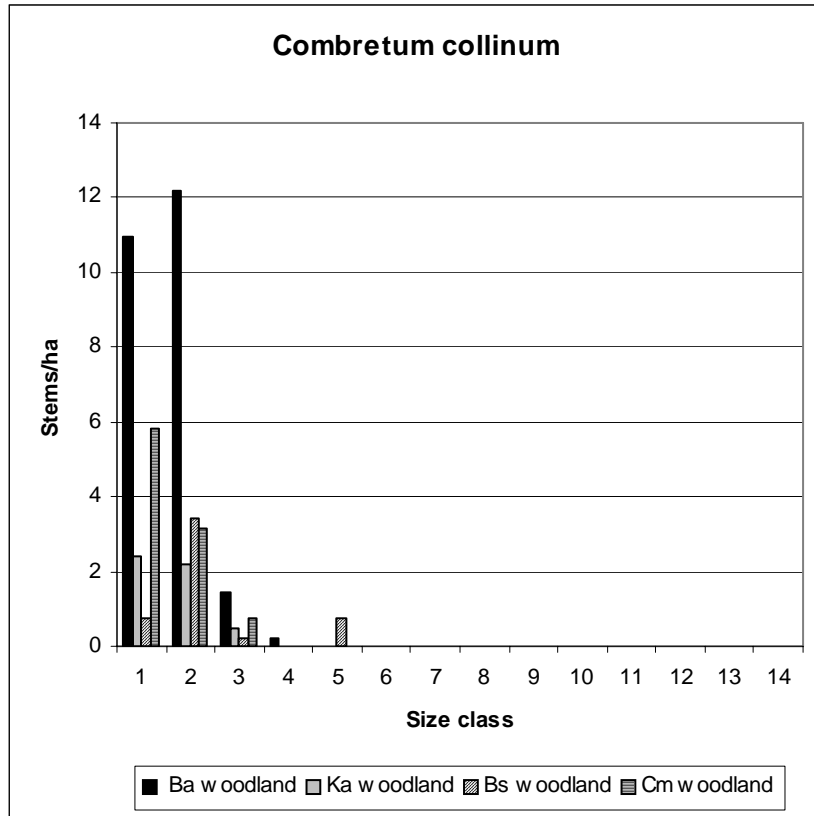


Figure 2(e). The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Combretum collinum*.

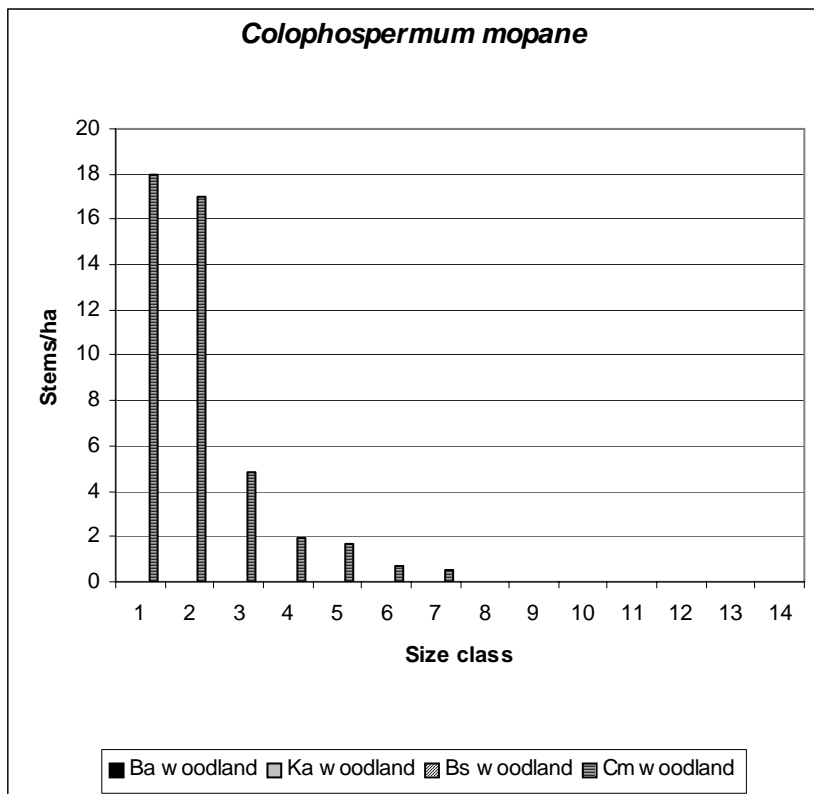


Figure 2(f) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Colophospermum mopane*.

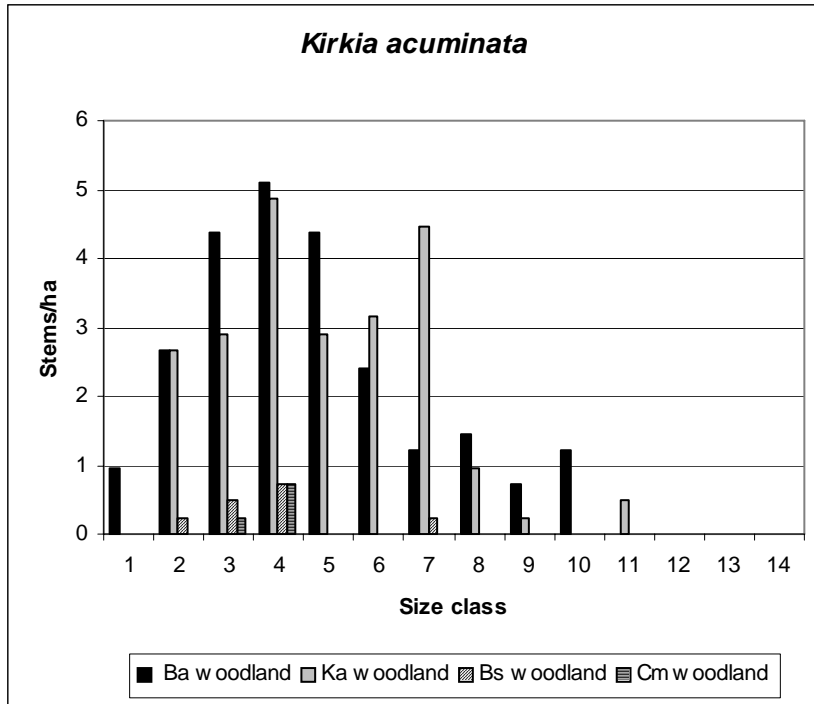


Figure 2(g) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Kirkia acuminata*.

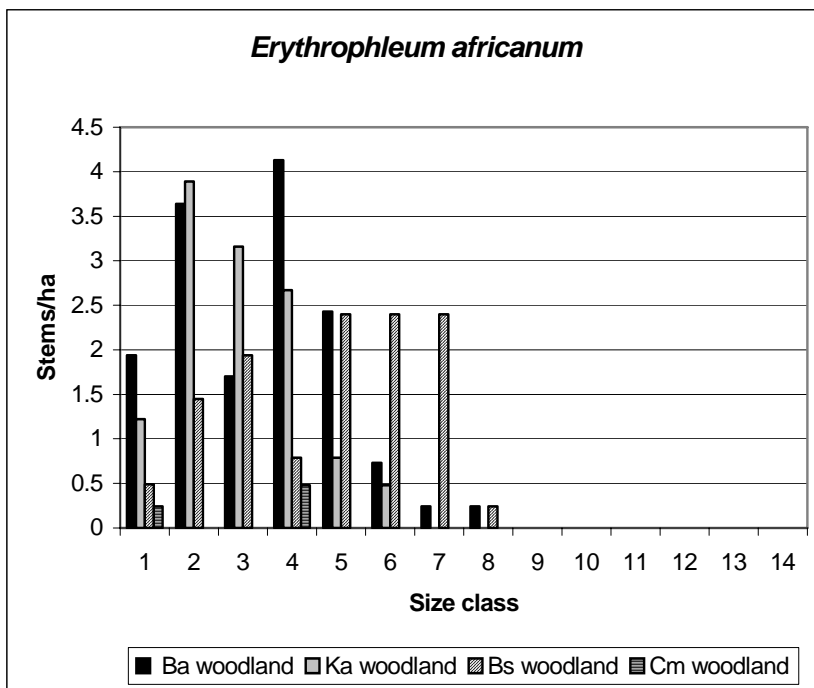


Figure 2(h) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Erythrophleum africanum*.

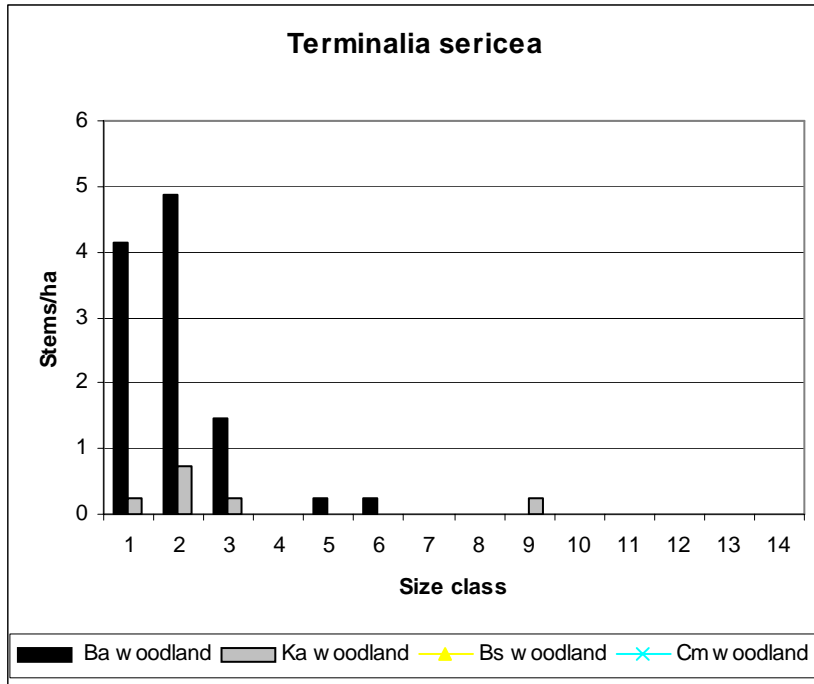


Figure 2(i) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Terminalia sericea*.

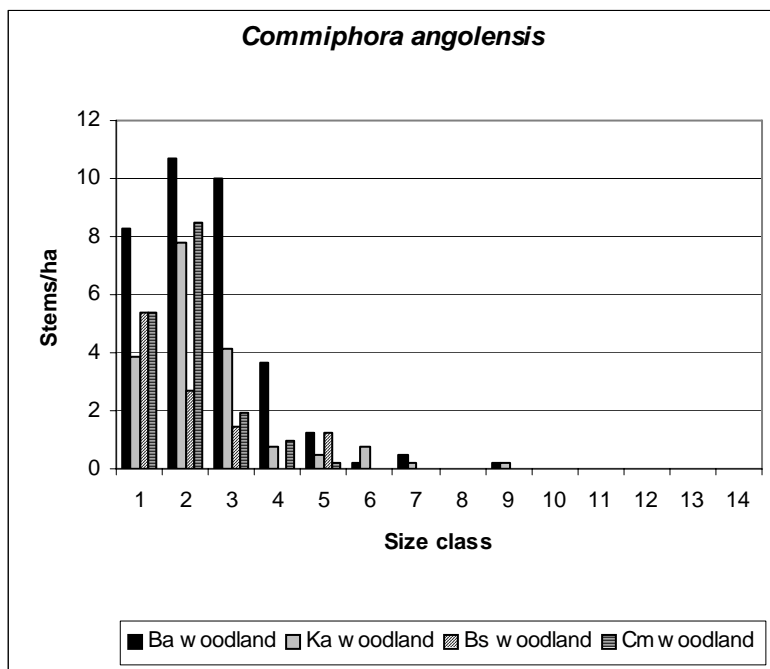


Figure 2(j). The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Commiphora angolensis*.

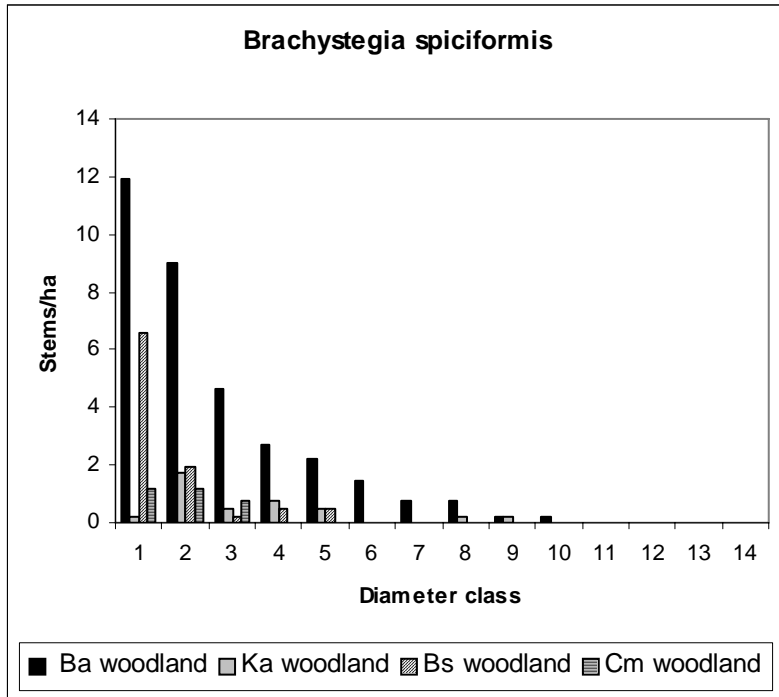


Figure 2(k) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Brachystegia spiciformis*.

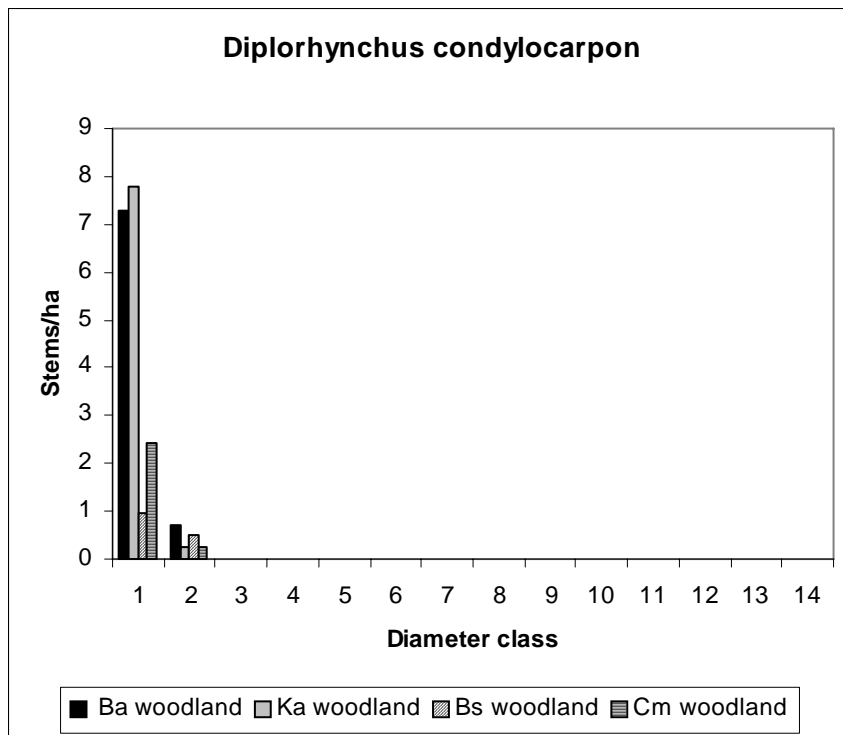


Figure 2(l) The variation in population structure of selected woody species in Fuller and Mafungabusi forest reserves: *Diplorhynchus condylocarpon*.