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COPPICE REGENERATION IN SOME MIOMBO WOODLANDS OF MALAWI

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ABSTRACT

Miombo woodlands in three different areas within Malawi were coppiced in 1992 and assessed to determine the woodlands' ability to regenerate from coppice. The number of shoots produced on each coppiced stump, the length and diameter of the leading shoot per stool, as well as the survival and mortality rates for cut stumps were measured or calculated. For the common miombo species, the experiment was designed to establish optimal cutting intensities and to generate information on wood production, growth potential and optimum rotations for specific products. The rate and vigour of coppice regeneration was monitored in plots coppiced at three intensities, namely: complete coppice, coppice with standards and selective thinning. A total of 76 woody species were recognised on the three study sites of which only two species were recorded as occurring on all sites. Despite the small size of the sample areas, a Detrended Correspondent Analysis (DECORANA) on the pre-felling growing stock at the three sites shows that there is a distinct variation in species composition between sites. The important environmental gradients responsible for this variation appear to be altitude, rainfall, soil moisture and nutrient status. Over the first four years after coppicing, DECORANA also indicated that coppicing does not significantly change the woodlands' composition. In each treatment, the survival and mortality rates for coppiced stumps is species specific but also depends on size, age, health and vigour of the trees felled. Mortality rate among cut stumps was highest in 'complete coppice' and least in 'selective thinning' plots reflecting the effect canopy cover has on stump survival and/or mortality. Overall, stump mortality increased where the proportion of trees having an initial diameter greater than 25 cm also increased. The relatively high stump mortality in complete coppice plots may therefore mirror a high proportion of large trees felled in this treatment. However, exposure of the resprouting stumps to evapo-transpiration in the complete coppice plots could also influence high mortality in large diameter classes. The effect the size of tree prior to coppicing has on stump survival was clearly evident at Dedza where stump mortality was higher than at Phuyu and Chimaliro. A high stump mortality was common for the most dominant species of *Brachystegia floribunda*, especially on stumps larger than 25-cm diameter. Other species that had noticeably high stump mortality include *Burkea africana*, *Pseudolachnostylis maprouneifolia*, *Cussonia arborea*, *Brachystegia boehmii* and *Uapaca kirkiana*. Using General Linear Models (GLM), taking diameter of trees cut as a covariate, an Analysis of Variance (ANOVA) shows that one year after felling there were significant differences ($p > 0.05$) in species mean height and diameter growth between sites, between treatments and in blocks within sites. No interaction between treatments and sites was noted. In subsequent years, however, site was the only factor that consistently displayed a source of variation in height and diameter growth, while other factors did not vary significantly. Incremental height and diameter growth was noticeably higher in the more open treatments (complete coppice and coppice with standards) than in the relatively closed selective thinning plots. Using GLM, the number of shoots produced per stool appeared independent of size of tree coppiced For the dominant miombo species of the genera *Brachystegia* and *Julbernardia*, a maximum number of shoots were produced on stumps with a diameter between 20 and 25 cm. This study has demonstrated that coppicing can be employed as a means of regenerating and managing miombo woodlands. The high rate of stool mortality among large-size stumps is likely to affect woodland stocking in the long term. To increase stocking at sites where coppice shoot production is low, it is suggested that coppicing is combined with soil scarification which enhances root suckering. Regeneration from root suckers is evident for many years after cultivation. As a means of regenerating miombo, coppicing should be restricted to trees less than 25-cm diameter. This will increase the rate and vigour of coppice regeneration, enhance stool survival and reduce stump mortality.

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INTRODUCTION

In common with several sub-Sahara African countries, the dominant natural woodland type in Malawi is miombo. Miombo is a vernacular word that has been adopted by ecologists to describe the dry deciduous woodland ecosystems dominated by trees of the genera *Brachystegia*, *Julbernardia*, *Isoberlinia* and their associates (Malaisse 1978, Celander 1981, Kayambazinthu 1988, Lowore 1993, Grundy 1995). In Malawi, Mombo is the vernacular name for *Brachystegia boehmii* and *B. longifolia*. At present miombo extend across about 2.7 million km^2 of the African subhumid tropical zone from Tanzania and Zaire in the north, through Zambia, Malawi and eastern Angola, to Zimbabwe and Mozambique in the south. Although the composition and structure of miombo varies with soil quality, rainfall and land-use (Endean 1967), the trees are distinguished by the shape of the dominant trees which have short, slender boles with markedly ascending branches and light, shallow, flat-topped or umbrella shaped crowns (White 1983). The woodlands constitute the largest more-or-less contiguous block of deciduous tropical woodlands and dry forests in the world.

It is estimated that over 75 million people live within the miombo biome. The woodlands directly support the livelihood of about 39 million people in seven central African countries, including some with among the lowest *per capita* income and the highest *per capita* population growth rates in the world. A further 15 million people living in towns and cities throughout the miombo ecozone also depend on food, fibre, fuelwood and charcoal produced in miombo (Child 1996, Bradley and McNamara 1993, Dewees 1994).

Miombo woodlands have been described many times but their ecology, silviculture and management potential are still not well understood (Gauslaa 1989, Lowore 1993). A comprehensive understanding of the dynamic ecology of miombo is essential for their effective management. It is common knowledge that, when adequately protected from fire and grazing, miombo can regenerate naturally either from seed or through coppicing and root suckering. Under dry tropical conditions vegetative regeneration is more effective than seed regeneration which is more subject to the negative effects of fire and herbivory. Coppicing involves regeneration by stool shoots or suckers after cutting. When felled near ground level, most broad-leaved species, up to a certain age, reproduce from shoots sent up from the stump or stool (Matthews 1989). Coppicing has been used to regenerate and manage temperate woodlands from as early as the Greek and Roman times, if not earlier (Troup 1928, Champion and Griffiths 1948, Matthews 1989). Coppice shoots tend to be straight and grow faster than seedlings. Shifting cultivation, a farming system widely practised in the miombo ecozone, has provided ample opportunity for scrutinising regeneration patterns on fallow land. Most fallow land regeneration appears to be through root suckering (Fanshawe 1959, Tuite and Gardiner 1984, Lowore *et al.* 1993).

The Ndola Miombo Coppice Plots, located in the copper-belt province of Zambia, have provided valuable information on coppice regeneration when miombo are exposed to varying cutting intensities and different fire management regimes (Trapnell 1959, Endean 1961; 1968, Chidumayo 1988). Accurate productivity data based on long-term measurements of miombo are, however, still scarce (Gauslaa 1989). In Malawi some data on miombo coppice regrowth for poles and fuelwood production have been obtained from the Bunda Coppice Plots (Edwards 1982, Siddle

1995). However, comprehensive information on coppicing-ability and regrowth of miombo tree species is neither readily available nor substantiated. This paper presents some results on the rate and vigour of coppice regrowth in the first four years following coppicing in some woodlands in Malawi.

MATERIALS AND METHODS

Study Sites

Miombo extend from 5° to 25° south of the equator across the central African plateau. The woodlands are generally restricted to altitudes from 500 to 1500 m above sea level. The precise species composition of miombo varies with altitude, rainfall, soil quality, nutrient status and land-use history. In order to cover a representative sample of Malawi's miombo types, three study areas were identified in different ecotypes. These ranged from a low altitude dry miombo [Phuyu], to a wet plateau miombo [Chimaliro] and a montane hill miombo [Dedza] (Table 1).

Table 1: Location and Details of Silvicultural Systems Trials in Malawi

	PHUYU	DEDZA	CHIMALIRO
District (Region)	Chikwawa (S)	Dedza (C)	Kasungu (C)
Geographic Location	15° 54'S 34° 45'E	14° 23'S 34° 17'E	12° 28'S 33° 29'E
Altitude (m.a.s.l.)	500	1600	1200
Mean Annual Rainfall (mm)	750	1100	1000
Mean Basal Area (m^2 ha^{-1})	7.5	11.0	12.6
Stemwood : Branchwood Ratio	0.75	0.52	0.78
Stocking (sph - trees > 5 cm dbh)	383	466	748
Range of Stocking (stems per ha.)	248 - 520	288 - 720	376 - 1352
DBH (cm) Min/Mean/Max	4.0 12.9 47.0	5.0 15.3 42.0	4.0 13.9 38.0
Number of Species Sampled	34	26	47
Silvicultural Zone*	Ba	M	D

* Hardcastle 1978

Experimental Design

The silvicultural systems trial layout was a Complete Randomised Block Design (CRBD) with 4 treatments and 3 replications established on 3 sites. The treatments under observation were simple but proven systems of woodland management, namely: Complete Coppice, Coppice with Standards and Selective Thinning. A Control, with no felling, was included for comparison purposes. Within the study sites each replicate block was laid on a relatively uniform site. The proportion of trees felled per treatment varied from complete removal of the canopy (Complete Coppice), removal of 70-80% of the canopy (Coppice with Standards), and removal of 30-40% of the canopy in Selective Thinning plots. In the Control treatment all trees in the plot were left uncut. A silvicultural thinning criteria was used in determining what trees to remove in treatment plots. The dead, dying, diseased and crooked trees were removed first followed by a crown thinning leaving the retained trees more or less evenly spaced out. The trees retained as "standards" in the 'coppice-with-standards' plots had to be mature 'plus' trees of good form. These were trees having the potential to be utilised for timber or large posts. Standards also assume the role of mother trees, while others were retained solely for the purpose of bearing seeds of the preferred species. In addition it is important that genepool diversity is maintained and so rare species were included among an overall good mix of species retained in all treatment plots.

Trial Establishment

The Silvicultural Systems Trials under study were established between June and September 1992. Before the coppice treatments were imposed an inventory of all woody species occurring within the demarcated study plots was carried out - recording the species, diameter at breast height (DBH) in centimetres (cm) and height in metres (m). Only trees with a minimum DBH of 5 cm were enumerated in the inventory. A record of the utilisable woody composition of the growing stock was thus noted on all study sites. This information formed the baseline on which subsequent assessments and data analysis would be based.

Treatment plots were rectangular (50 m x 25 m) covering an area of 0.125 ha. A buffer zone of at least 10 m was allowed between treatment plots and replicate blocks. Permanent concrete marks and beacons were installed at plot centres, margins and corners points. All trees within sample plots were serially numbered prior to felling. A galvanised metal tag was firmly fixed to the base of each tree and stump bearing the original tree number allotted. Trees retained in the control and treatment plots were marked with a white band painted at 1.3 m above ground level, a point at which annual diameter measurements were taken. Compass bearings and horizontal distances from the plot centre of all samples trees were recorded, and a computerised record of this data maintained. Similarly, plot position data has been recorded using a Global Positioning System (GPS). The height at which sample trees were cut varied with tree size and between study sites. At Phuyu and Dedza sample trees up to 20 cm DBH were cut at ground level (between 15 to 20 cm above ground) while those with DBH greater than 20 cm were cut at 1.3 m above ground level. At Chimaliro trees of up to 15 cm DBH were felled at ground level while the remainder were cut at 1.3 m. In this context, felling at 1.3 m height is referred to as pollarding while that at ground level is called coppicing. Pollarding was employed because regrowth from pollards is better protected from fire and may be more suitable if the woodland is to be browsed by domestic animals (Lawton 1980). The Forestry Department of Malawi allows farmers to forage their animals in miombo forest reserves (Forestry Department 1996). As it is more convenient, farmers from the northern part of Malawi traditionally cut trees at about breast height when clearing woodlands for cultivation.

Data Collection

The growth parameters annually measured on each felled stump were length and diameter of the largest shoot, as well as the number of shoots produced per stool. Shoot diameters were taken at 10 cm above point of shoot emergence for uniformity and to avoid effects of butt swelling. Stump survival was calculated from the percentage of stools that survived compared with the original number of trees cut.

Data Analysis

Due to diversity in species composition and the variation in species abundance between plots, within and between treatments, as well as within and between sites, in some statistical analysis, only species whose sample of coppiced trees was large were included. In some cases mean parameter and/or plot values were used in the analysis. The majority of examples are drawn from the performance of *Brachystegia* and *Julbernardia* species, the miombo canopy dominants in Malawi. Other results presented are from measurements of some commonly occurring species.

RESULTS

Woodland Composition and Population Structure
A total of 76 woody species were recognised across the study sites (Appendix 1) of which only two species, *Flacourtia indica* and *Lannea discolor*, were recorded as common to all sites. Woodland stocking and basal area distribution varied with prevailing soil and climatic conditions, the driest site, at Phuyu, was least stocked while Chimaliro was most densely stocked (Table 1). The combined pre-felling species abundance on all sites forms a typical *De Liocourt* curve (Negative Exponential Model), the dominant miombo and associated species being prevalent (Figure 1). Near normal (skewed) distribution curves are formed when pre-felling stem diameter distributions are graphically plotted for all sites (Figure 2). Normal dbh distribution curves are more clearly evident for the gazetted forest reserves (Dedza and Chimaliro) where, as a result of restricted harvesting, canopy closure has occurred. With the light demanding nature of most miombo species, canopy closure reduces the rate of regeneration and vigour of shoot growth. The dbh model for Phuyu is more skewed and therefore similar to the *De Liocourt* curve model (Figure 2). A multivariate analysis using Detrended Correspondence Analysis (DECORANA - refer to Hill and Gauch 1980; Kent and Coker 1992) on the initial composition of the growing stock indicates that there is significant variation in species composition between miombo types across Malawi (Figures 3). The x-axis on Figures 3 shows that there are more species common to the wet sites of Dedza and Chimaliro than between Phuyu and either of these former sites. This would suggest that altitude, and therefore temperature and moisture availability, are important environmental gradients influencing the composition of miombo woodlands at different sites. Localised patterns in pre-felling species composition was also evident from ordination of species composition and abundance in treatment plots (Figure 4).

Stump Survival
Survival of coppiced stumps is important in determining species' coppicing-ability and the effectiveness of coppicing as a means of managing miombo. Stump survival varied considerably between species, treatments and sites (Table 2 and Figures 5 & 7). Four years after coppicing poor survival was notable among the large stumps (those > 25cm dbh) of canopy dominants and associated species, including *Brachystegia boehmii*, *B. floribunda*, *Pseudolachnostylis maprouneifolia* and *Uapaca kirkiana*. For some large canopy dominant species stump survival fell below 50% (Table 2). As shown in Figure 7, however, other miombo co-dominant species stump survival was well over 60%. With a stump survival below 30%, *Cussonia arborea* suffered the highest mortality among common miombo understorey species (Table 2). After four years following coppicing there was 100% stump mortality for *Burkea africana*, *Commiphora africana*, *Lonchocarpus bussei* and *Parinari curatellifolia*. All the coppiced stumps of *Burkea africana* were of DBH greater than 25 cm (Appendix 1) while only a single specimen was felled for each of *Commiphora africana* and *Parinari curatellifolia*. Over the first four years trends in stump survival in treatments suggest that percentage canopy cover has a bearing on stump mortality, survival being

Figure 1: **Pre-felling Species Stocking (stems per hectare) on all sites [1992]**
Each dot represents a species stocking in the three study sites [see appendix 1]

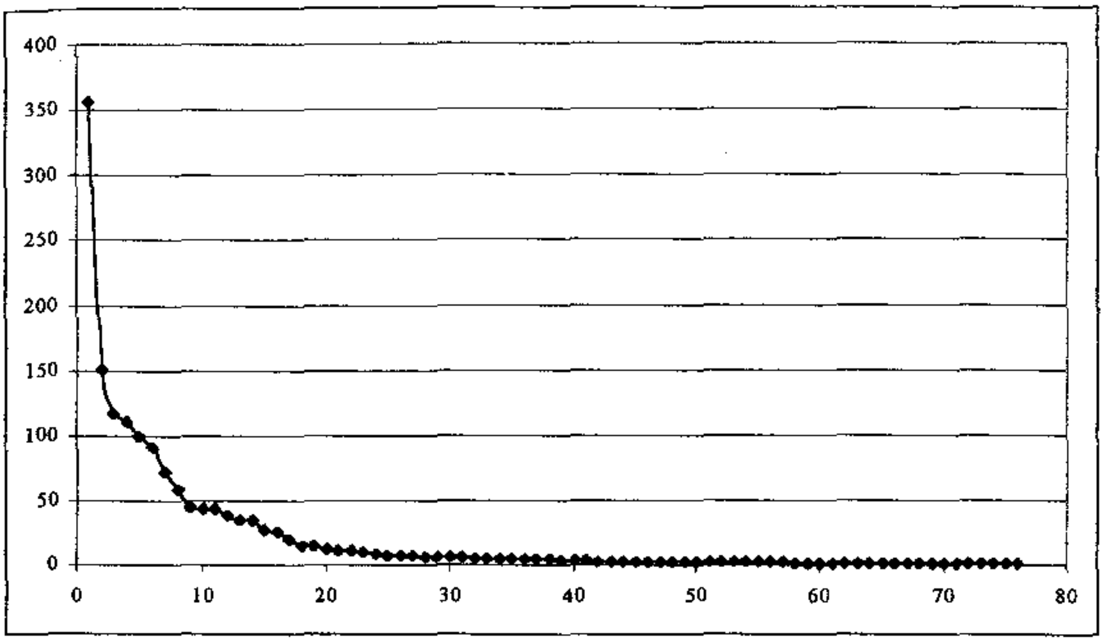


Figure 2: **Pre-felling trees diameter distribution at the three sites [1992]**

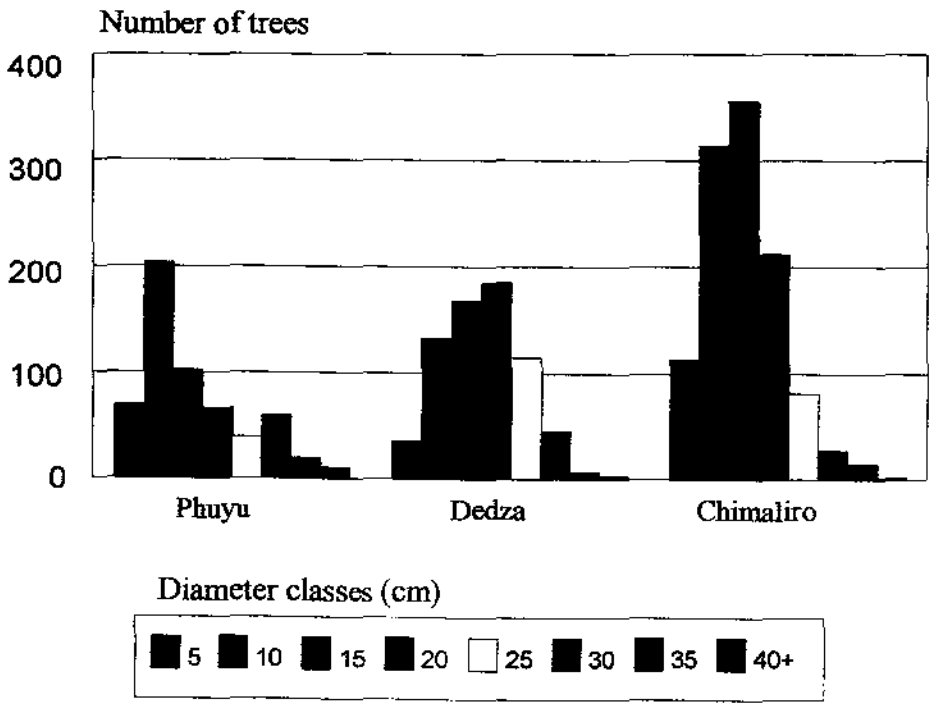


Figure 3: **Pre-felling DECORANA ordination for species composition on all the three sites [1992]**

{Only trees ≥ 5-cm dbh enumerated} [A full species list in Appendix 1]

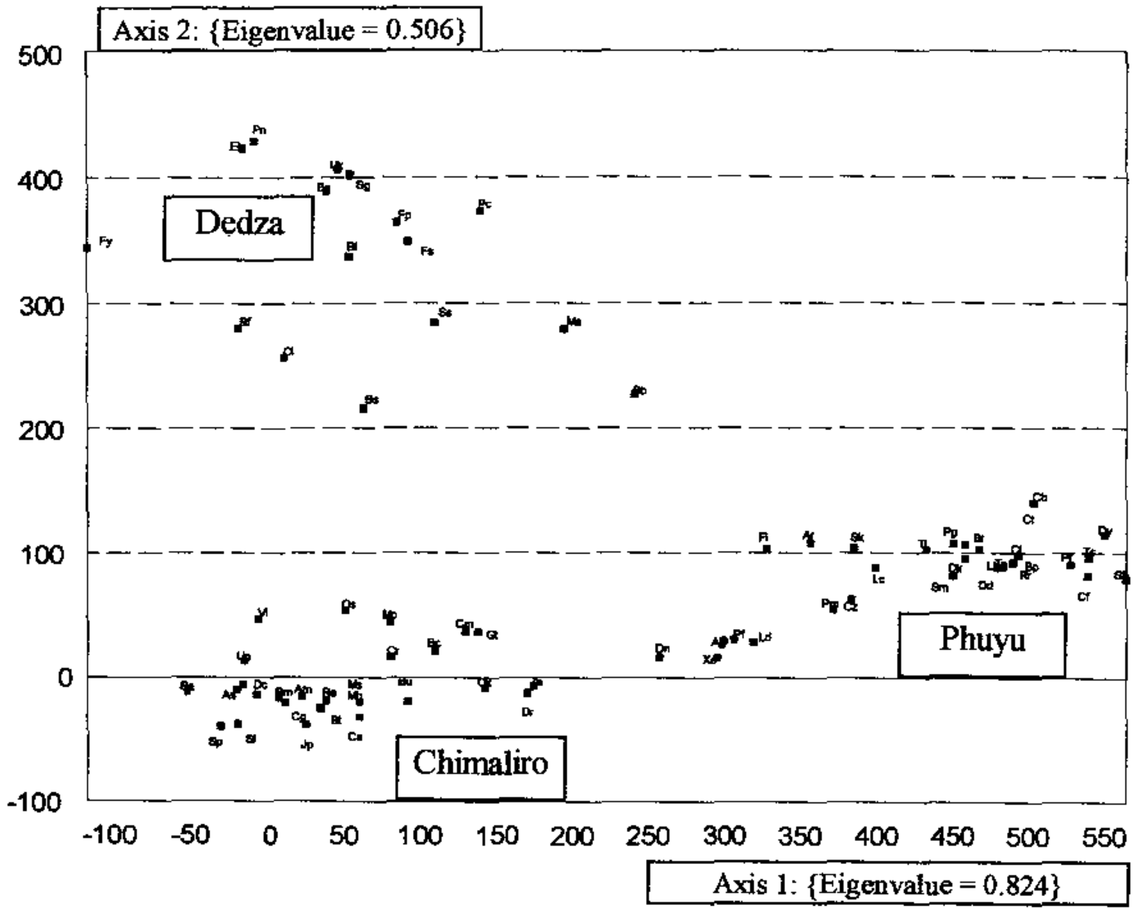


Figure 4: **Pre-felling Detrended Correspondence Analysis Sample Ordination for all sites [1992]**

-Each symbol represents species composition in treatment plots as well as the ordination position of each treatment plot at a given site.

-Each plot was 0.125 ha. [50 m by 25 m].

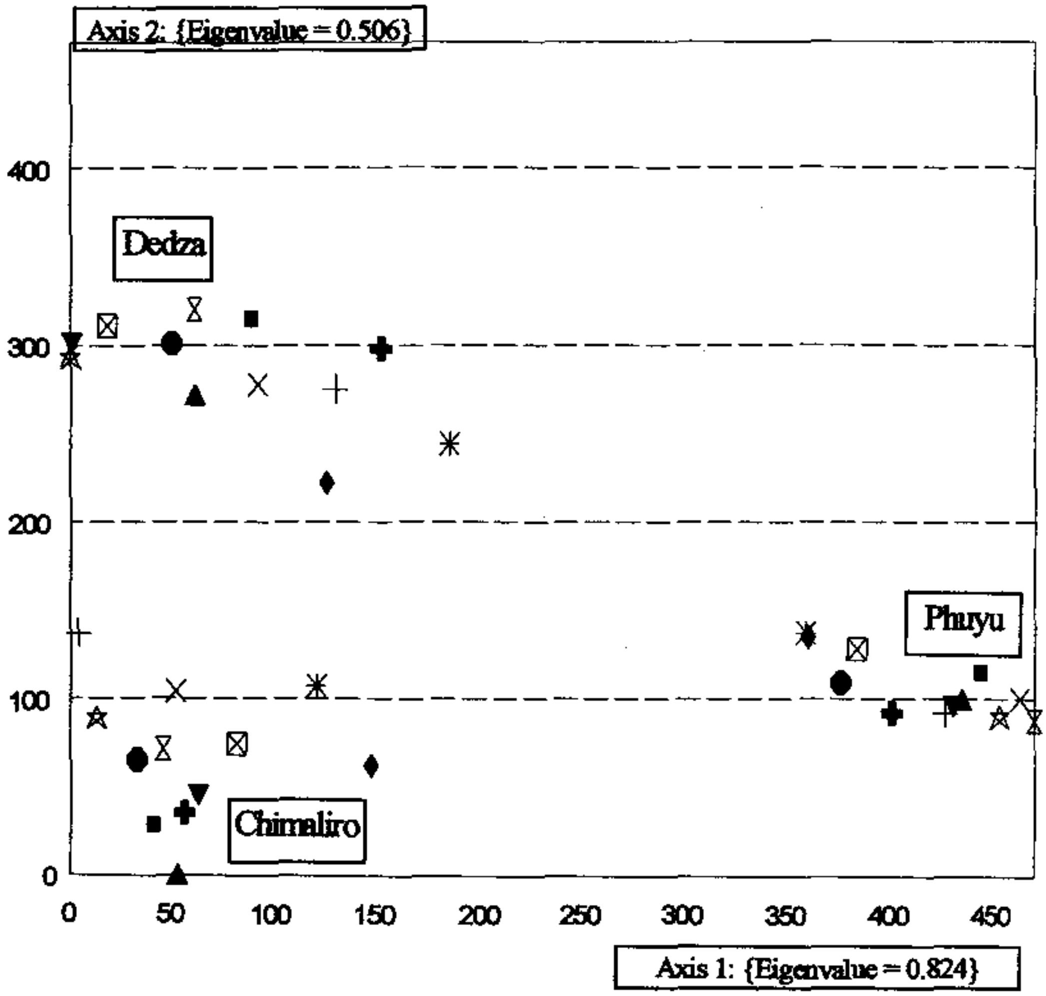


Figure 5: Mean Annual Stump Survival Percentage in Treatments

STH = Selective Thinning
CWS = Coppice With Standards
COC = Complete Coppice

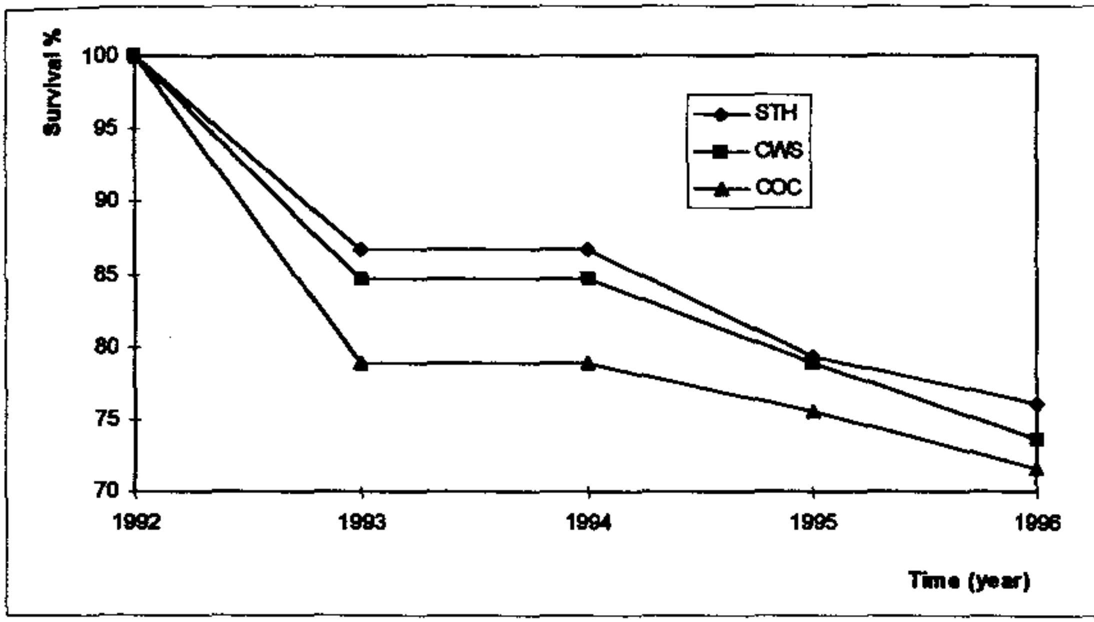
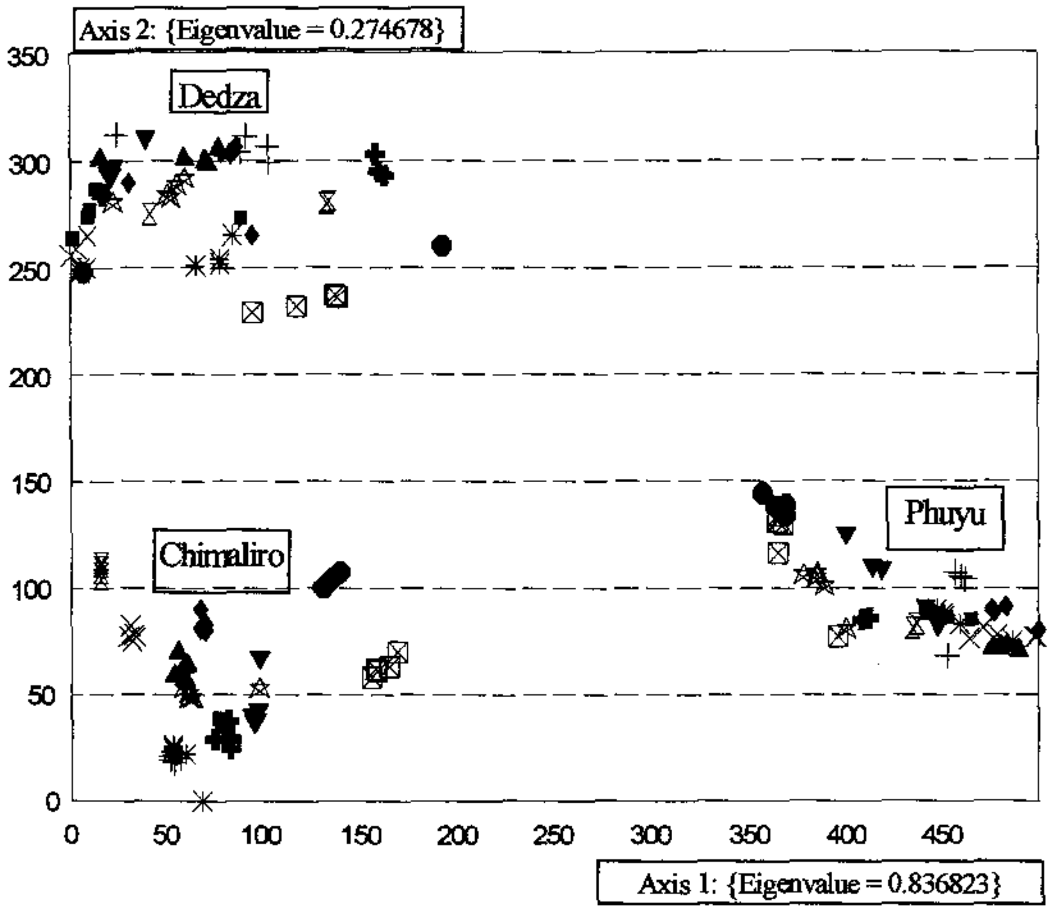


Figure 6: Post-felling DECORANA Ordination for Sample composition on all sites for the period 1992 to 1996 [Only trees ≥ 5-cm dbh were initially enumerated]

-Each symbol represents species composition in a treatment plot.

-a cluster of symbols with the same sign portrays the shift in annual variation in treatment composition from 1992 through to 1996.

-treatment plots = 0.125 ha in size.

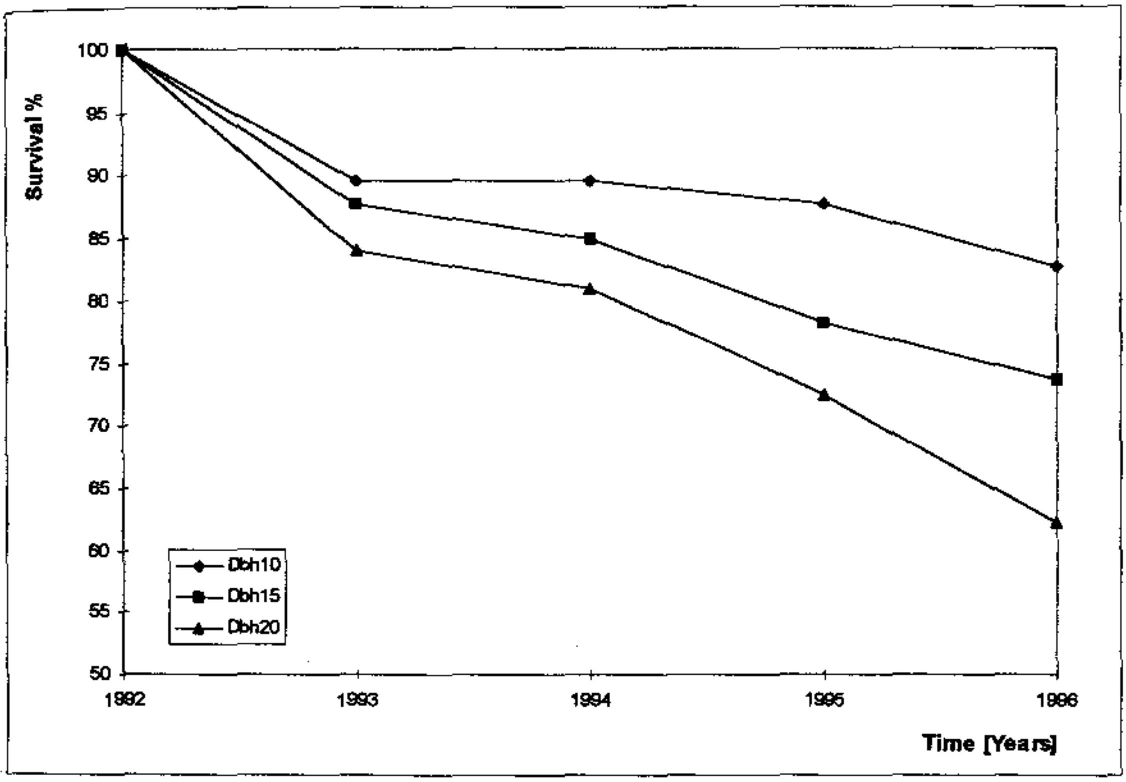


higher in 'selective thinning' than 'complete coppice' plots (Figure 5). This may be due to a high exposure of cut stumps to evapo-transpiration and effects of fire. Compared with other treatments the high mortality in complete coppice plots may also reflect a higher proportion of large-size trees cut. Stump mortality was higher at Dedza than Phuyu. Dedza is the wettest of the three sites (Table 1), as such the reasons for the high stump mortality are probably related to factors other than moisture availability. These may include poor soil nutrient status, a genotypical variation in the miombo type that occurs in Dedza, stump death as a result of some pathogenic agencies such as the *Armillaria mellea* fungus, a high proportion of large-sized *Uapaca kirkiana* or because a significant proportion of the initial crop comprised large (senescent) trees. During the 1996 assessments a physical observation of trees retained in treatment plots indicated that there was a high proportion of *Brachystegia* species showing signs of shoot dieback. A combined post-felling sample ordination for the period 1992 to 1996 indicates a considerable shift in the species composition for some treatments at Dedza (Figure 6).

Table 2: Survival of coppiced stumps for some common miombo species

Species	DBH Class [cm]	Number Cut 1992	Survival % 1993	Survival % 1994	Survival % 1995	Survival % 1996	Structural Position
Acacia amythethophylla	10	15	80	80	73	80	Under-storey Species
	15	13	77	77	85	85	
	20	4	75	75	75	75	
Bauhinia petersiana	10	46	100	96	98	93	Under-storey Species
	15	12	83	83	83	92	
	20	4	100	100	100	100	
Brachystegia boehmii	10	9	89	89	89	89	Canopy Dominant Species
	15	15	73	73	73	73	
	20	10	90	90	90	90	
	25	8	88	88	75	63	
	30+	17	59	59	59	29	
Brachystegia floribunda	10	22	68	64	59	45	Canopy Dominant Species
	15	57	61	61	61	60	
	20	91	58	58	53	49	
	25	57	93	84	70	56	
	30	25	88	72	44	40	
	35+	12	75	67	42	33	
Brachystegia manga	10	11	91	91	91	91	Canopy Dominant Species
	15	19	89	89	84	79	
	20	14	100	100	93	93	
	25	9	89	78	78	78	
Brachystegia spiciformis	10	22	91	91	86	86	Canopy Dominant Species
	15	18	72	67	67	61	
	20	11	82	82	73	55	
	25+	14	86	86	64	57	
Brachystegia utilis	10	21	90	90	90	90	Canopy Dominant Species
	15	21	95	90	90	86	
	20	14	93	93	86	86	
	25	8	88	88	88	63	
Combretum fragrans	10	5	100	100	100	100	Under-storey Species
	15	7	100	100	100	100	
Cussonia arborea	10	10	90	80	60	50	Under-storey Species
	15	11	64	64	55	36	
	20	7	71	43	43	14	
	25+	6	67	67	17	17	
Diospyros kirkii	10	16	94	94	88	88	Canopy Co-dominant Species
	15	13	87	87	87	87	
	20	10	100	100	100	100	
Diplorynchus condylocarpon	10	33	97	97	97	94	Under-storey Species
	15	14	100	100	100	100	
	20	7	100	100	100	100	
Julbernardia paniculata	10	38	95	95	92	92	Canopy Dominant Species
	15	56	93	93	88	86	
	20	29	93	93	90	90	
	25	13	92	85	77	62	
Pericopsis angolensis	10	14	100	100	93	93	Canopy Co-dominant Species
	15	8	100	100	100	100	
	20	4	100	100	100	100	
Pseudolachnostylis maprouneifolia	10	10	70	70	70	50	Canopy Co-dominant Species
	15	9	78	67	44	44	
	20	11	82	82	55	27	
Pterocarpus rotundifolius	10	13	92	92	92	92	Canopy Co-dominant Species
	15	4	100	100	100	100	
	20	8	88	75	75	75	
Uapaca kirkiana	10	68	96	96	96	96	Canopy Co-dominant Species
	15	22	73	73	68	50	
	20	8	75	63	63	63	
	25	7	71	71	57	29	

Figure 7: Combined mean annual survival % for some canopy co-dominant species using the stump size of trees coppiced
Species include: *Diospyros kirkii, Pericopsis angolensis, Pseudolachnostylis maprouneifolia, Pterocarpus rotundifolius* and *Uapaca kirkiana.*



Shoot Production

The annual quantity of stool shoots produced varies between species (see Table 3). Among the most prolific coppicers are *Acacia amythethophylla, Annona senegalensis, Bauhinia petersiana, B. thonningii, Combretum* spp., *Diospyros kirkii, Diplorynchus condylocarpon, Brachystegia utilis, Ficus sycommorus, Flacourtia indica, Pericopsis angolensis, Pseudolachnostylis maprouneifolia, Pterocarpus rotundifolius, Terminalia* spp., *Uapaca* spp., *Ximenia caffra* and *Xeroderris stuhlmannii.*

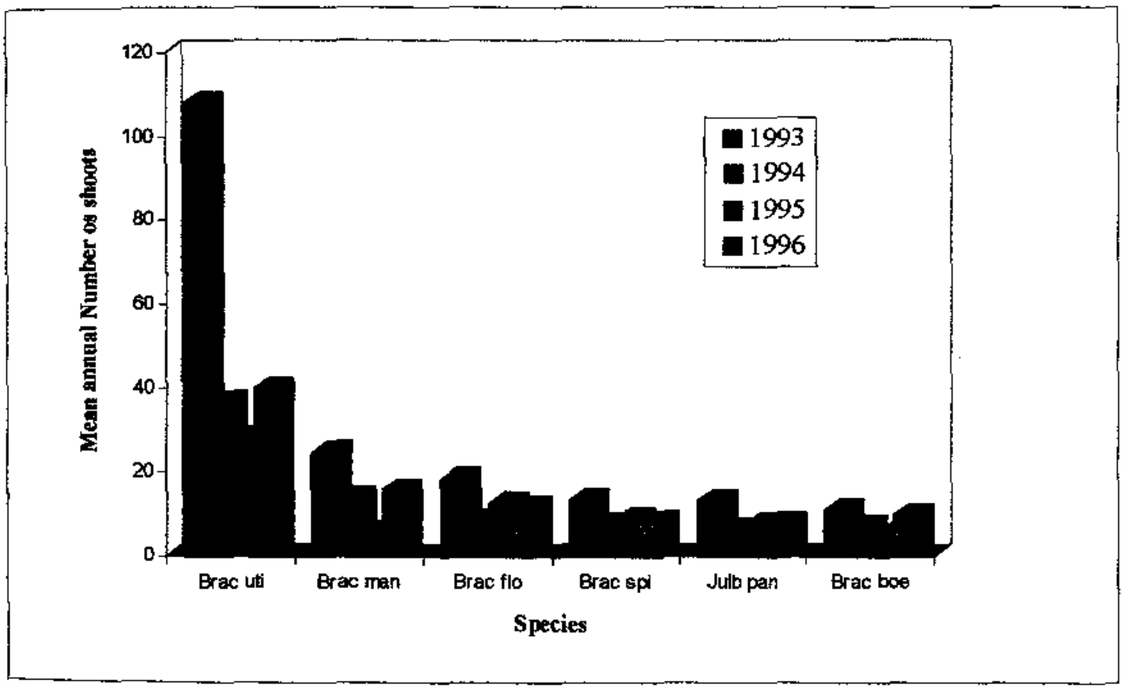
For some species the quantity of shoots produced increased with stump size. For most species, however, number of shoots produced and retained on the stumps was not dependent on stump size (Table 3). Taking the mean diameter of trees originally coppiced as a covariate, an Analysis of Variance (ANOVA) using General Linear Models (GLM) indicates that there were no significant differences in the mean number of shoots produced between treatments, sites, and between blocks within treatments; neither was there any site x treatment interaction in shoot production throughout the first 4 years following coppicing.

Table 3: Mean annual number of stool shoots produced by some common species

Species	DBH Class [cm]	Number Cut 1992	Number of stool shoots 1993	Number of stool shoots 1994	Number of stool shoots 1995	Number of stool shoots 1996	Structural Position
Acacia amythethophylla	10	15	7	5	4	4	Understorey
	15	13	9	6	5	4	
	20	4	11	12	7	6	
Bauhinia petersiana	10	46	14	8	6	8	Understorey
	15	12	12	15	8	5	
	20	4	8	6	4	10	
Brachystegia boehmii	10	9	5	5	5	5	Canopy Dominant
	15	15	8	8	4	6	
	20	10	20	11	6	12	
	25	8	9	5	5	8	
	30	5	14	10	8	14	
	35+	12	21	11	8	24	
Brachystegia floribunda	10	22	9	4	4	3	Canopy Dominant
	15	57	10	4	6	6	
	20	91	18	8	11	11	
	25	57	28	12	21	16	
	30	25	27	12	31	16	
	35+	12	38	18	16	30	
Brachystegia manga	10	11	25	16	4	10	Canopy Dominant
	15	19	18	10	4	6	
	20	14	28	15	7	17	
	25	9	28	15	8	30	
Brachystegia spiciformis	10	22	7	5	6	5	Canopy Dominant
	15	18	8	5	6	5	
	20	11	11	5	6	6	
	25	5	12	7	8	6	
	30+	9	43	24	28	26	
Brachystegia utilis	10	21	15	7	5	5	Canopy Dominant
	15	21	19	10	7	8	
	20	14	43	10	8	14	
	25	8	31	10	8	13	
Combretum fragrans	10	5	6	2	2	2	Understorey
	15	7	7	4	2	4	
Cussonia arborea	10	10	4	4	3	3	Understorey
	15	11	4	4	5	4	
	20+	13	14	7	6	7	
Diospyros kirkii	10	16	9	4	3	7	Understorey
	15	13	14	6	6	9	
	20	10	10	6	8	13	
Diplorynchus condylocarpon	10	33	15	7	7	12	Understorey
	15	14	18	8	10	14	
	20	7	11	5	6	13	
Julbernardia paniculata	10	38	12	5	5	6	Canopy Dominant
	15	56	13	7	6	7	
	20	29	13	6	8	8	
	25	12	28	13	19	17	
Pericopsis angolensis	10	14	23	5	7	7	Canopy Co-dominant
	15	8	16	6	9	9	
	20	5	40	7	18	13	
Pseudolachnostylis maprouneifolia	10	10	23	7	11	12	Canopy Co-dominant
	15	9	29	6	5	6	
	20	11	59	16	25	41	
Pterocarpus rotundifolius	10	13	9	4	4	7	Canopy Co-dominant
	15	4	13	10	10	15	
	20	8	8	3	4	4	
Uapaca kirkiana	10	68	13	8	6	5	Canopy Co-dominant
	15	22	12	8	8	8	
	20	8	12	12	9	10	
	25	7	35	7	8	5	

Apart from *Brachystegia utilis* the other canopy dominant species do not seem to coppice profusely (Figure 8). In general, a high number of shoots were produced in the first year following coppicing. There was then a drastic reduction in number of shoots surviving the following year, after which shoot production slows down until a constant number is retained (see Figure 8). This self-thinning phenomenon is probably the result of intra-specific stool shoot competition (Matthews 1989). As can be seen from Figure 7 there was generally a modest increase in the mean number of shoots produced in year 4. This may have been a response to the favourable rains that fell in the 1996 rainy season following three years of drought in the region.

Figure 8: Mean annual number of stool shoots produced on some canopy dominants



Height Growth

Mean shoot height growth for some common miombo species is presented in Table 4. Taking stump diameter as a covariate, an ANOVA using GLM on the first year's height growth indicates a significant variation in the mean height between treatment plots, between sites and in blocks within sites. The analysis also showed that the size of the trees felled had a bearing on initial height growth, however, there was no site x treatment interaction in mean height growth (Table 5a). In subsequent years stump size did not appear to influence height growth as variation in mean height was only apparent between treatments and sites; neither was there site x treatment interaction (Table 5b). As illustrated by the standard error bars on Figure 9, mean annual height growth among the dominant *Brachystegia* spp. varied considerably between species

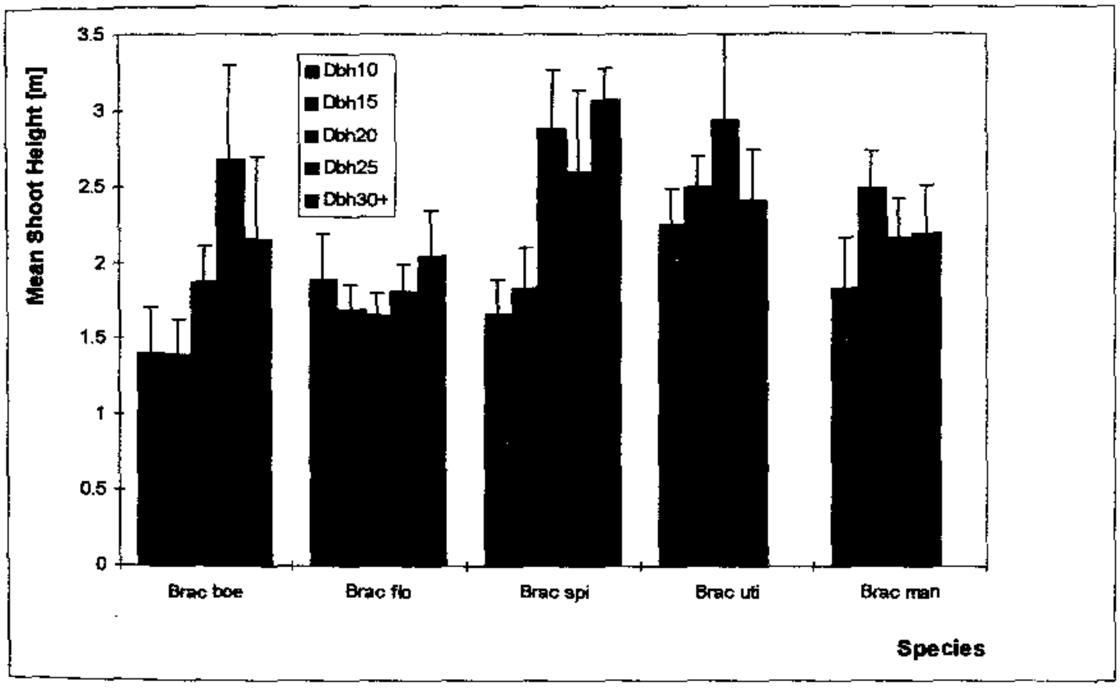
Table 4: Mean height [m] of 4-year-old coppice shoots of common species

Species	DBH Class [cm]	Number cut 1992	Mean Shoot Height [m] 1996	Standard Error	Mean Annual Height Increment [m] by dbh class	Species' Mean Annual Height Increment [m] 93-96
Acacia amythethophylla	10	15	2.96	0.09	0.74	
	15	13	3.18	0.07	0.80	**0.77**
	20	4	3.10	0.19	0.78	
Bauhinia petersiana	10	46	3.27	0.02	0.82	
	15	12	3.21	0.09	0.80	**0.85**
	20	4	3.75	0.26	0.94	
Brachystegia boehmii	10	9	1.40	0.09	0.35	
	15	15	1.39	0.06	0.35	
	20	10	1.87	0.06	0.47	**0.58**
	25	8	2.68	0.39	0.67	
	30	17	2.37	0.38	0.59	
	35	4	1.94	0.21	0.49	
Brachystegia floribunda	10	22	1.88	0.09	0.47	
	15	57	1.68	0.03	0.42	
	20	91	1.65	0.02	0.41	**0.46**
	25	57	1.81	0.03	0.45	
	30	25	1.73	0.06	0.43	
	35+	12	2.36	0.12	0.59	
Brachystegia manga	10	11	1.83	0.11	0.46	
	15	19	2.49	0.06	0.62	**0.54**
	20	14	2.16	0.07	0.54	
	25	9	2.18	0.11	0.55	
Brachystegia spiciformis	10	22	1.66	0.05	0.42	
	15	18	1.83	0.07	0.46	
	20	11	2.88	0.15	0.72	**0.60**
	25	5	2.60	0.28	0.65	
	30+	9	3.06	0.05	0.77	
Brachystegia utilis	10	21	2.25	0.06	0.56	
	15	21	2.50	0.04	0.63	**0.63**
	20	14	2.93	0.33	0.73	
	25	8	2.41	0.11	0.60	
Combretum fragrans	10	5	2.49	0.25	0.62	
	15	7	3.45	0.27	0.86	**0.74**
Cussonia arborea	10	10	0.74	0.03	0.19	
	15	11	0.52	0.07	0.13	**0.15**
	20+	7	0.53	0.09	0.13	
Diospyros kirkii	10	16	1.84	0.04	0.46	
	15	13	1.85	0.05	0.46	**0.43**
	20	10	1.48	0.08	0.37	
Diplorynchus condylocarpon	10	33	2.29	0.03	0.57	
	15	14	2.49	0.13	0.62	**0.55**
	20	7	1.79	0.15	0.45	
Julbernardia paniculata	10	38	1.54	0.02	0.39	
	15	56	1.65	0.01	0.41	**0.41**
	20	29	1.66	0.03	0.42	
	25	13	1.73	0.07	0.43	
Pericopsis angolensis	10	14	1.82	0.06	0.46	
	15	8	2.05	0.04	0.51	**0.47**
	20	4	1.71	0.14	0.43	
Pseudolachnostylis maprouneifolia	10	10	2.61	0.16	0.65	
	15	9	1.55	0.17	0.39	**0.48**
	20	11	1.57	0.34	0.39	
Pterocarpus rotundifolius	10	13	3.01	0.09	0.75	
	15	4	2.38	0.44	0.60	**0.62**
	20	8	2.09	0.19	0.52	
Uapaca kirkiana	10	68	1.74	0.01	0.44	
	15	22	1.70	0.05	0.43	**0.37**
	20	8	1.23	0.14	0.31	
	25	7	1.20	0.00	0.30	

Table 5a: Analysis of Variance for mean shoot height [1993]

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Avdbh92	1	0.81508	0.04133	0.04133	7.38	0.020
Sitecode	2	3.98431	3.84087	1.92043	342.95	0.000
Blocode (Sitecode)	6	0.43390	0.47786	0.07964	14.22	0.000
Trtcode	2	0.07029	0.08581	0.04290	7.66	0.008
Sitecode*Trtcode	4	0.05342	0.05342	0.01336	2.38	0.115
Error	11	0.06160	0.06160	0.00560		
Total	26	5.42760				

Figure 9: Mean shoot height for 4-year-old coppice shoots for some *Brachystegia* Specie using stump size



and diameter classes, *Brachystegia spiciformis* and *B. utilis* out-competing other canopy dominants in this regard. For most *Brachystegia* species maximum height was attained on stumps whose diameter was less than 25cm. There was a declining trend in height of shoots on stumps larger than 30cm diameter (Figure 9).

Table 5b: Analysis of Variance for mean shoot height [1996]

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Avdbh92	1	0.63944	0.02287	0.02287	0.37	0.554
Sitecode	2	2.05574	1.90192	0.95096	15.47	0.001
Blocode(Sitecode)	6	0.35541	0.33962	0.05660	0.92	0.516
Trtcode	2	0.61082	0.58015	0.29008	4.72	0.033
Sitecode*Trtcode	4	0.70545	0.70545	0.17636	2.87	0.075
Error	11	0.67600	0.67600	0.06145		
Total	26	5.04286				

Among common canopy co-dominant species *Pterocarpus rotundifolius* grew faster than *Pseudolachnostylis maprouneifolia, Pericopsis angolensis* and *Uapaca kirkiana*. The best height growth was achieved among small stumps of 10-15 cm DBH (Figure 10). Among common understorey species *Bauhinia petersiana, Acacia amythethophylla* and *Combretum fragrans* grows extremely fast, attaining mean heights above 3 m within the first four growing seasons (Figure 11). With a mean height below 1 m after four years *Cussonia arborea* grows least among common understorey species. As a species *Bauhinia petersiana* is usually restricted to the understorey. Field observation during the 1996 assessments showed that a number of leading shoots for this species were typically dying back. At four years the species appeared to have attained its maximum height growth already.

Figure 10: Mean height for four-year-old coppice shoots of some common canopy co-dominant species

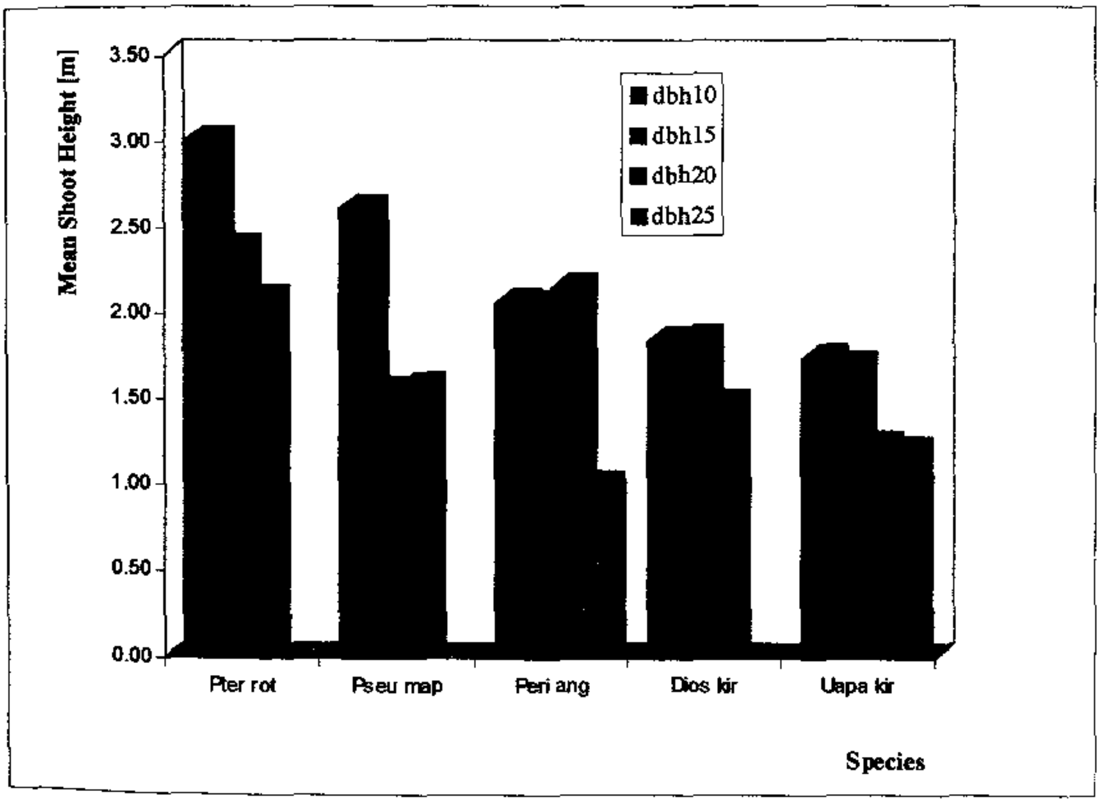
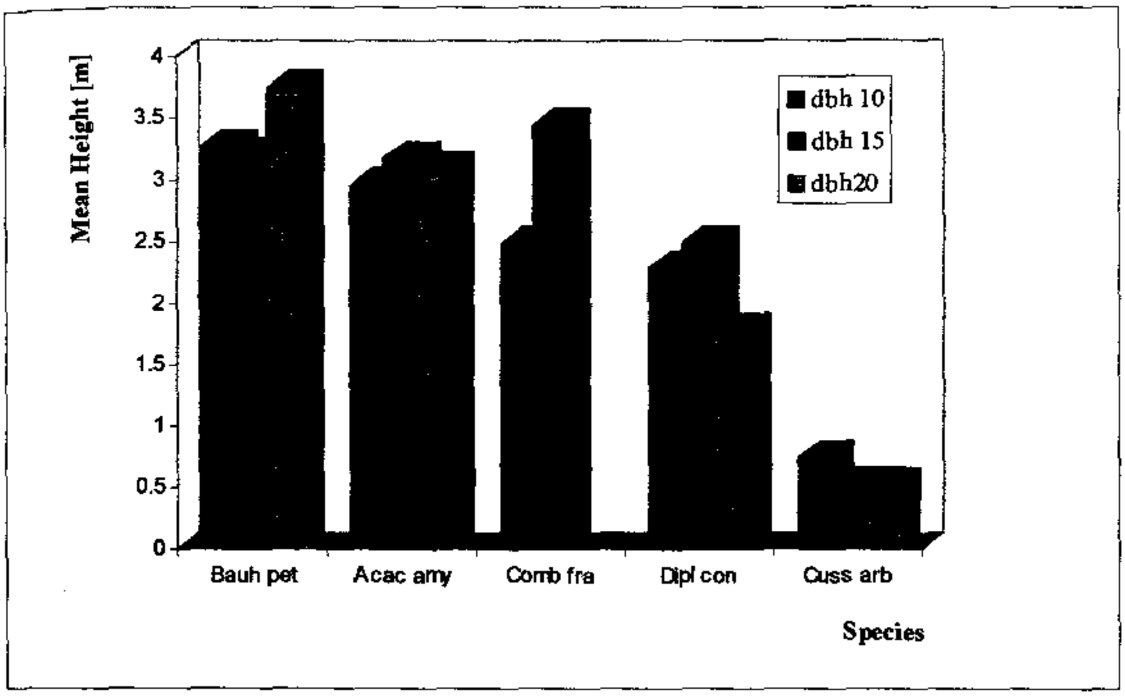


Figure 11: Mean height for four-year-old coppice shoots of some common understorey species



Diameter growth
Shoot diameter growth varied considerably between species and size classes (Table 7). As is the case with height growth, an ANOVA using GLM shows that initially there is significant variation in mean shoot diameter between treatments, sites, and between blocks within sites (Table 6a).

Table 6a: Analysis of Variance for Mean Shoot Diameter [1993]

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Avdbh92	1	0.55585	0.00463	0.00463	0.24	0.637
Sitecode	2	2.40783	2.24098	1.12049	57.08	0.000
Blocode (Sitecode)	6	0.60511	0.61968	0.10328	5.26	0.009
Trtcode	2	0.36471	0.38184	0.19092	9.73	0.004
Sitecode*Trtcode	4	0.14761	0.14761	0.03690	1.88	0.184
Error	11	0.21594	0.21594	0.01963		
Total	26	4.29705				

Table 6b: Analysis of Variance for Mean Shoot Diameter [1996]

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Avdbh92	1	0.2328	0.0473	0.0473	0.38	0.548
Sitecode	2	0.5702	0.7021	0.3510	2.85	0.100
Blocode (Sitecode)	6	1.2119	1.2765	0.2127	1.73	0.204
Trtcode	2	3.7997	3.6382	1.8191	14.78	0.001
Sitecode*Trtcode	4	1.2080	1.2080	0.3020	2.45	0.108
Error	11	1.3539	1.3539	0.1231		
Total	26	8.3765				

Site x treatment interaction in shoot diameter growth was not apparent (Table 6a). This pattern of growth was not maintained in subsequent years, as significant variation in diameter growth was noticeable only between treatments (Table 6b). Diameter growth increased with stump size for canopy dominants, maximum shoot diameters being attained on stumps with DBH between 20 to 30 cm for most species (Table 7). Among canopy dominants *Brachystegia boehmii* and *B. spiciformis* had higher diameter increments than others, *Brachystegia floribunda* and *Julbernardia paniculata* achieving the least diameter growth. Despite high stump mortality, diameter growth for *Uapaca kirkiana* and *Pseudolachnostylis maprouneifolia* supersedes that of the other canopy co-dominants (Figure 12). Common understorey species of *Acacia amythethophylla* and *Bauhinia petersiana* put on more shoot diameter growth than *Cussonia arborea, Diospyros kirkii, Diplorynchus condylocarpon* and *Combretum fragrans* (Figure 13). In most species diameter growth is fastest in the first few years (Figures 12 and 13).

Site x treatment interaction in shoot diameter growth was not apparent (Table 6a). This pattern of growth was not maintained in subsequent years, as significant variation in diameter growth was noticeable only between treatments (Table 6b). Diameter growth increased with stump size for canopy dominants, maximum shoot diameters being attained on stumps with DBH between 20 to 30 cm for most species (Table 7). Among canopy dominants *Brachystegia boehmii* and *B. spiciformis* had higher diameter increments than others, *Brachystegia floribunda* and *Julbernardia paniculata* achieving the least diameter growth. Despite high stump mortality, diameter growth for *Uapaca kirkiana* and *Pseudolachnostylis maprouneifolia* supersedes that of the other canopy co-dominants (Figure 12). Small sized stumps among miombo canopy co-dominant species appear to put on more diameter growth than large stumps, of which *Uapaca kirkiana* had a higher mean shoot diameter. Common understorey species of *Acacia amythethophylla* and *Bauhinia petersiana* put on more shoot diameter growth than *Cussonia arborea, Diospyros kirkii, Diplorynchus condylocarpon* and *Combretum fragrans* (Figure 13).

Table 7: Mean diameter [cm] of 4-year-old coppice shoots for some species

Species	DBH Class [cm]	Number cut 1992	Mean Shoot Diameter [cm] 1996	Standard Error	Mean Annual Diameter Increment [cm] by dbh class	Species' Mean Diameter Increment [cm] 93-96
Acacia amythethophylla	10	15	5.63	0.45	1.41	
	15	13	5.57	0.29	1.39	**1.44**
	20	4	6.03	0.82	1.51	
Bauhinia petersiana	10	46	5.44	0.17	1.36	
	15	12	5.70	0.41	1.43	**1.41**
	20	4	5.77	0.44	1.44	
Brachystegia boehmii	10	9	3.56	0.49	0.89	
	15	15	3.49	0.43	0.87	
	20	10	3.52	0.20	1.08	**1.08**
	25	8	3.96	0.67	0.99	
	30	5	6.70	0.00	1.68	
	35+	12	3.80	0.76	0.95	
Brachystegia floribunda	10	22	3.86	0.43	0.97	
	15	57	3.21	0.22	0.80	
	20	91	3.52	0.20	0.88	**0.98**
	25	57	3.69	0.22	0.92	
	30	25	4.01	0.36	1.00	
	35+	12	5.03	0.45	1.26	
Brachystegia manga	10	11	3.18	0.48	0.80	
	15	19	5.43	0.34	1.36	**1.06**
	20	14	4.07	0.32	1.02	
	25	9	4.23	0.49	1.06	
Brachystegia spiciformis	10	22	3.72	0.30	0.93	
	15	18	4.29	0.38	1.07	
	20	11	5.73	0.54	1.43	**1.22**
	25	5	4.75	0.50	1.19	
	30+	9	5.88	0.42	1.47	
Brachystegia utilis	10	21	4.38	0.34	1.09	
	15	21	4.79	0.29	1.20	**1.20**
	20	14	5.28	0.34	1.32	
	25	8	4.80	0.42	1.20	
Combretum fragrans	10	5	3.06	0.57	0.77	
	15	7	4.51	0.50	1.13	**0.95**
Cussonia arborea	10	10	3.52	0.46	0.88	
	15	11	2.73	0.57	0.68	**0.71**
	20+	7	2.30	0.46	0.58	
Diospyros kirkii	10	16	3.29	0.30	0.82	
	15	13	3.50	0.30	0.88	**0.84**
	20	10	3.28	0.43	0.82	
Diplorynchus condylocarpon	10	33	3.81	0.20	0.95	
	15	14	3.66	0.44	0.92	**0.95**
	20	7	3.86	0.47	0.97	
Julbernardia paniculata	10	38	3.43	0.19	0.86	
	15	56	3.86	0.16	0.96	**0.94**
	20	29	3.37	0.20	0.84	
	25	13	4.45	0.46	1.11	
Pericopsis angolensis	10	14	3.50	0.31	0.88	
	15	8	3.73	0.33	0.93	**0.93**
	20	4	3.90	0.45	0.98	
Pseudolachnostylis maprouneifolia	10	10	5.42	0.61	1.36	
	15	9	2.98	0.63	0.75	**0.99**
	20	11	3.43	0.98	0.86	
Pterocarpus rotundifolius	10	13	4.28	0.35	1.07	
	15	4	2.93	0.72	0.73	**0.83**
	20	8	2.80	0.50	0.70	
Uapaca kirkiana	10	68	4.97	0.16	1.24	
	15	22	4.62	0.42	1.16	**1.03**
	20	8	3.48	0.64	0.87	
	25	7	3.40	0.46	0.85	

Figure 12: Mean annual diameter [cm] of coppice shoots for some common canopy co-dominant species

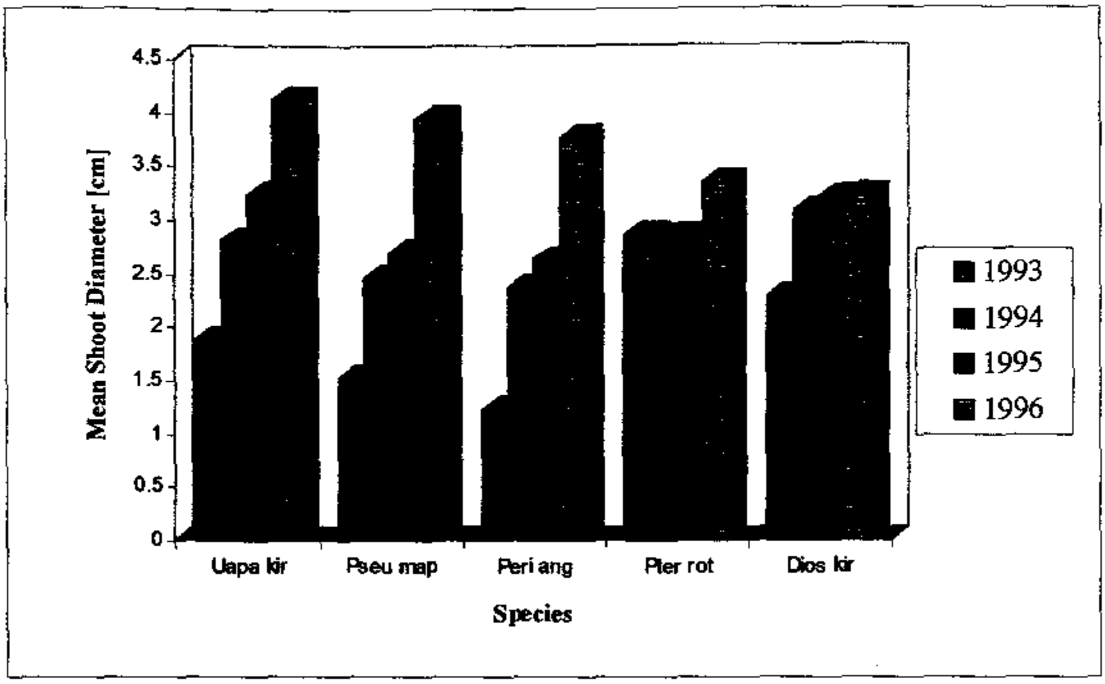
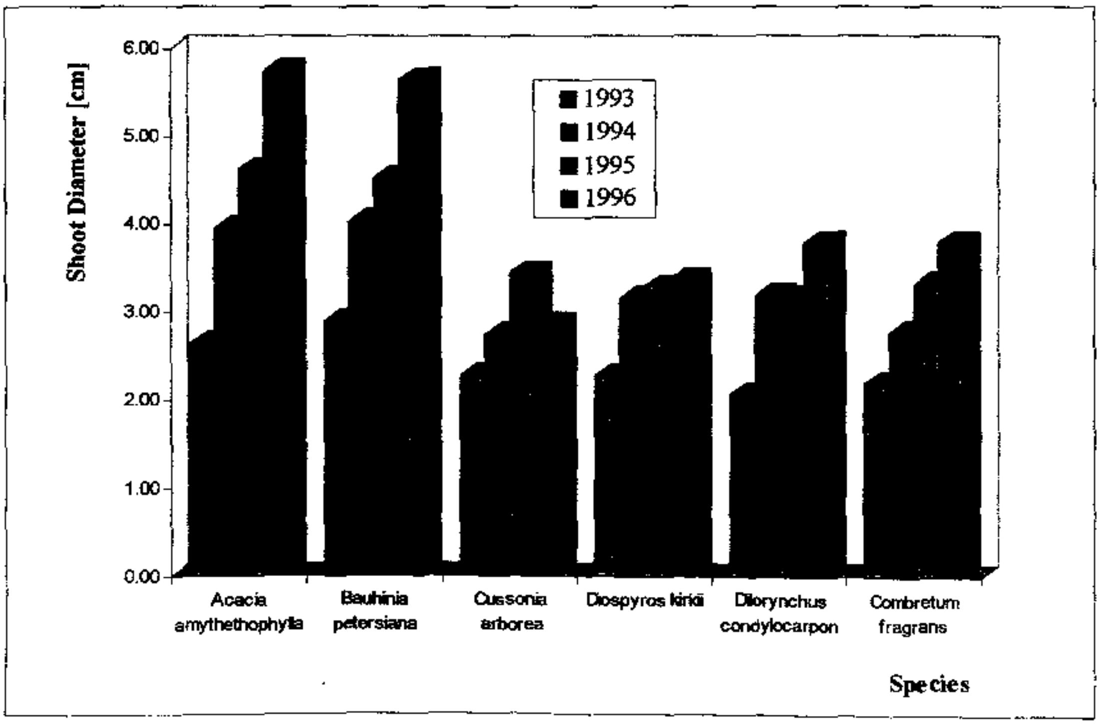


Figure 13: Mean annual diameter growth [cm] for some common understorey species



DISCUSSION

Species Coppicing ability

Of the 76 species recognised across the three study sites *Cassia abbreviata*, *Combretum imberbe*, *Cyphostemma tridentata*, *Dombeya rotundifolius*, *Maytenus senegalensis*, *Multidentia crassa*, *Pleurostylia africana*, *Rhus longipes*, *Sclerocarya birrea* subspp. *caffra*, *Seculidaca longipedunculata* and *Vitex payos* were not represented in the sample of coppiced trees. These uncoppiced species occurred at very low densities in the woodlands. Of the trees that were represented in the coppice samples, only two species, *Commiphora africana* and *Parinari curatellifolia* did not produce coppice shoots. However, only a single tree was coppiced for each of the two species. This is therefore too small a sample size from which to conclude that the two species do not coppice at all. *Parinari curatellifolia* is, however, known to regenerate profusely on previously cultivated land through root suckers. Overall, the number of trees that produced coppice shoots represents a coppicing-ability above 95% for miombo woodland species.

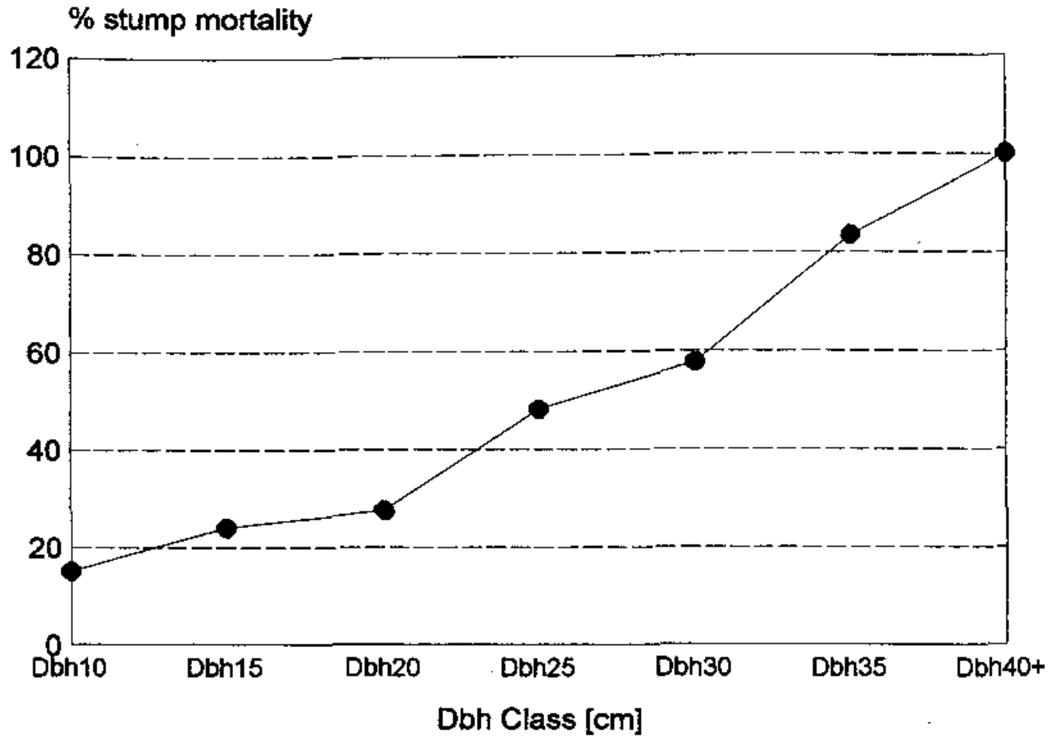
Stump Survival

Coppice stools are not immortal. Fanshawe (1959) observed that on a firewood rotation of approximately 40 years, 40% of the stools died when they were clearfelled. In his study Fanshawe found that mortality was higher in large-sized stools, compared to smaller stools. Observations carried out in Malawi also indicate that stump survival is higher among small-size stools than larger ones (Adlard 1964, Edwards 1982). The present study confirms that stump mortality is high among large-sized stools, notably those of *Brachystegia boehmii*, *B. floribunda*, *Burkea africana*, *Cussonia arborea*, *Lonchocarpus bussei*, *Parinari curatellifolia*, *Pseudolachnostylis maprouneifolia* and *Uapaca kirkiana* (Figure 13). It is only for *Burkea africana*, *Commiphora africana*, *Lonchocarpus bussei* and *Parinari curatellifolia* that 100% stump mortality has been recorded over the four-year period since coppicing. Apart from a few species such as *Brachystegia floribunda*, *Cussonia arborea* and *Pseudolachnostylis maprouneifolia*, mortality among small size stumps (< 15 cm dbh) was well below 20% (Table 2). This strongly suggests that coppicing in miombo woodlands should take into account the size, age and vigour of trees cut. To ensure a vigorous and high rate of regrowth coppicing should be restricted to trees less than 25 cm DBH (figure 14). For most wood products (poles and firewood in particular) shorter coppice rotations 15 to 25 years should be considered. Shorter rotations tend to lengthen the life of the stools by keeping stool vigour renewed regularly (Fanshawe 1959).

Shoot Production

Certain species are more prolific in shoot production than others, notably *Bauhinia petersiana*, *Brachystegia floribunda*, *Diplorynchus condylocarpon*, *Julbernardia paniculata*, *Pericopsis angolensis*, *Pseudolachnostylis maprouneifolia*, *Syzygium guineense*, *Terminalia stenostachya* and *Uapaca kirkiana*. The number of shoots produced per stool varies between species and appears to be independent of stump size, treatment and site. However, for certain species, notably canopy dominants, shoot production increases with size of stump felled. An abundant number of shoots are produced in the first year following coppicing. A drastic reduction in the number of shoots retained at each stool is observed in the following year, after which a gradual reduction in number of shoots on each stool is observed until a consistent

Figure 14: Cumulative % stumps mortality for four-year-old regrowth of all coppiced trees using dbh class and transformed survival data



number is retained. Other than damage from fire and browsing, intra-specific stool shoot competition for light and nutrients would appear to be the major cause of this self-thinning tendency. This process can be aided through deliberate thinning from which produce in the form of light poles, firewood and rope fibre could be procured.

Shoot Growth

Shoot height and diameter growth varied between species, treatments and sites. There was greater incremental growth in the open 'complete coppice' and 'coppice with standards' plots than the closed 'selective thinning' treatments. Growth rates at the cooler but wetter site of Dedza were poorer than at the other two sites, namely Phuyu and Chimaliro. Poor growth rates at Dedza can not be clearly explained in the absence of precise information on soil status and site history. However it would be speculated that cooler temperatures, variation in the miombo type that occurs at Dedza, low soil nutrient status as well as a high proportion of species that are by nature poor coppicers (*Uapaca kirkiana* and *Brachystegia floribunda*) may all have a bearing on this poor growth performance.

In the initial stages of growth understorey species such as *Acacia amythethophylla, Annona senegalensis, Bauhinia petersiana, B. thonningii, Combretum apiculatum, Dalbergia nitidula* and *Ficus sycommorus* put on more mean height and diameter increment than the dominant overstorey species. Among canopy co-dominant species *Acacia nigrescens Pterocarpus rotundifolius* and *Uapaca nitida* grew as fast as some of the fastest growing understorey species. Among some canopy and associated species *Brachystegia longifolia, B. spiciformis, B. utilis, Pseudolachnostylis maprouneifolia* and *Uapaca kirkiana* performed relatively well in both height and diameter growth, while others including *Brachystegia boehmii, B. floribunda, B. manga, Julbernardia paniculata* and *Pericopsis angolensis* generally did poorly. For most understorey species growth was inversely related to stump size while for certain overstorey species height and diameter growth increased with stump size, on average peaking at stumps of between 20 and 25 cm diameter.

Coppice Management

Miombo is generally not considered as a climatic climax but fire climax woodland (Malaisse 1978). Chidumayo (1988) describes miombo as a kind of climax vegetation, whose maintenance is often reinforced by fire and other anthropogenic disturbances. Miombo woodlands are resilient enough to withstand some disturbance from cutting, grazing and fire. However, persistent disturbances from late dry season fires and overgrazing can severely reduce productivity and destroy the woodlands altogether. The coppice regrowth in the study area was adequately protected from fire and grazing through implementation of a recommended "controlled early burning" fire regime. The data provided in this report reflects growth under controlled fire management regimes. Fire control is the most important factor that should be considered in managing miombo coppice regrowth.

Under the above management structure coppice regrowth was more vigorous in the open 'complete coppice' plots than in the closed 'selective thinning' treatments. However, stump mortality was higher in 'complete coppice plots than in 'selective thinning' plots. This pattern of survival and growth is probably a direct response to the amount of light availability as most miombo species are thought to be light demanding.

Of the three treatments under study the choice of system for managing and harvesting miombo is dependent on many factors other than wood productivity. The amount and end-use of wood desired, terrain conditions, environmental and other conservation constraints all impinge on choice of cutting system and size of felling coupes. Carrying out an inventory of a large and heavily utilised block of dry miombo along the Shire valley Abell (1993) recommended a 'coppice with stands' system of management to provide both short terms wood products from the coppice and large dimension timber from the standards. However, complete coppice can be employed where short rotation firewood is desired, e.g. from fast growing understorey species such as *Acacia amythethophylla, Bauhinia* and *Combretum* species. To curtail soil erosion small felling coupes should be used when a 'complete coppice' cutting systems is employed. Selective thinning would be desirable where specific products are required in limited quantities. A typical example would be procurement of domestic implements that utilise high wood density species such as *Pericopsis angolensis, Swartzia madagascariensis, Combretum* spp. and *Terminalia* spp.

As far as possible harvesting should be conducted on a sustainable basis ensuring that conditions that enhance natural regeneration prevail after cutting.

CONCLUSION

After four years of coppice regrowth, stool shoots that have been produced have hardly attained pole stage. It is therefore too early to interpret coppice wood production in terms of volume output per hectare at this early developmental stage. However, the data presented above suggests that generally there is a difference in survival and growth rates between the canopy dominants on the one hand and understorey species on the other. *Acacia amythethophylla*, *Bauhinia petersiana* and *Diplorynchus condylocarpon* coppice vigorously, grow very fast initially and maintain a high rate of stump survival (Lowore *et al.* 1995). These species form part of the miombo understorey and shrub layer. Their fast initial growth is probably a response to the amount of light available after canopy opening. Such species can be managed on short rotation (10-15 years) for provision of domestic poles and firewood (Abell 1993; Lowore *et al.* 1994; Abbot *et al.* 1995). Canopy dominants tend to coppice less profusely, grow more slowly and have high stump mortality particularly for large and old trees. However, some of the canopy species, including *Brachystegia boehmii*, *B. spiciformis* and *B. utilis*, grow fast enough to provide rope fibre on a short rotation of between 5 and 10 years. These species could also be managed for production of domestic firewood on a 10 to 15 years coppice rotation (Abbot *et al* 1995; 1996). Canopy dominants can be managed on longer rotations for timber, large poles and industrial fuelwood production.

This study has shown that miombo can be regenerated and managed through a coppice systems as long as the woodlands are kept in juvenile state through use of short rotations. A 'coppice with standards' system of management is preferred over complete coppicing because it ensures a permanent woodland cover while providing the desired mix of products. This system also guarantees a source of supplementary regeneration from seeds provided by the standards. In woodlands where rate and vigour of coppice is low, soil scarification would be tried to enhance root suckering. Coppice regeneration should be protected from fire through a 'controlled early burning' fire management regime. The size of felling coupes should be kept small to curtail erosion.

Appendix 1: Pre-felling species composition, abundance and stocking

Species	Abv.	Diameter (DBH) Class [cm] 5	10	15	20	25	30	35	40+	Total	Stocking [sph]
Brachystegia floribunda	Bf	12	46	135	178	107	47	7	2	534	356
Julbernardia paniculata	Jp	7	52	100	53	11	3			226	151
Brachystegia boehmii	Bb	5	15	42	40	27	20	18	8	175	117
Uapaca kirkiana	Uk	25	73	38	20	8	2	1		167	111
Brachystegia utilis	Bu	12	45	53	24	14	1	1		150	100
Brachystegia spiciformis	Bs	4	27	39	30	19	8	7	2	136	91
Diplorynchus condylocarpon	Dd	16	60	18	10	3	1			108	72
Bauhinia petersiana	Bp	31	39	14	3					87	58
Cussonia arborea	Cr	4	13	26	15	8	1			67	45
Diospyros kirkii	Dk	7	26	17	11	1	1		1	64	43
Pseudolachnostylis maprouneifolia	Pm	4	19	18	16	6			1	64	43
Zahna africana	Sa	17	9	3			30			59	39
Pericopsis angolensis	Pa	6	25	8	7	3	3	1		53	35
Acacia amythethophylla	Am	2	18	17	7	1	1			46	35
Pterocarpus rotundifolius	Pr	5	14	9	7	5				40	27
Lannea discolor	Ld	3	21	10	4			1		39	26
Faurea saligna	Fs	1	4	8	6	6	4		1	30	20
Ochna schweinfurthiana	Os	2	18	2	1					23	15
Pterocarpus angolensis	Pg		6	3	4	4	2	2	1	22	15
Brachystegia manga	Bm			10	7	2				19	13
Flacourtia indica	Fi	6	11							17	11
Brachystegia longifolia	Bl	1	7	3	4	1				16	11
Combretum fragrans	Cg	5	7	3						15	10
Annona senegalensis	As.		5	6	2					13	9
Combretum apiculatum	Ca		4	7	1					12	8
Combretum molle	Cm	2	5	2		1	1			11	7
Dichrostachys cinerea	Dc	1	9							10	7
Strychnos spinosa	Sp	3	6							9	6
Faurea speciosa	Fp		3	4	1	1				9	6
Terminalia stenostachya	Tt		1	5	3					9	6
Lonchocarpus capassa	Lc			1	3	2	2	1		9	6
Burkea africana	Br					1	4	2	1	8	5
Acacia goetzei	Ag	1	4	2	1					8	5
Uapaca nitida	Un	3	3	1						7	5
Combretum zeyheri	Cz		6	1						7	5
Monotes africanus	Ma		3	3	1					7	5
Syzygium guineense	Sg	4	1	2						7	5
Terminalia sericea	Ts		2	3	1	1				7	5
Ximenia caffra	Xc		4	2						6	4
Parinari curatellifolia	Pc		1	3	1	1				6	4
Bridelia cathartica	Bc	1	4		1					6	4
Xeroderris stuhlmannii	Bc		1	1		1	2			5	3
Bauhinia thonningii	Bt		3	2						5	3
Cyphostemma tridentanta	Ct		5							5	3
Dalbergia nitidula	Dn		2	3						5	3
Lonchocarpus bussei	Lb		2	1		1			1	5	3
Albizzia antunesiana	An	1	3		1					5	3
Serma singueana	Ss		4	1						5	3
Ozoroa insignis	Oi	1		1	1	1				4	3
Pleurostylia africana	Pf	1	3							4	3
Bersama abyssinica	Ba	2			1					3	2

Appendix 1: [Continued] Pre-felling species composition, abundance and stocking [1992]

Species	Abv.	Diameter (DBH) Class [cm] 5	10	15	20	25	30	35	40+	Total	Stocking [sph]
Gardenia ternifolia	Gt	3								3	2
Erica benguerensis	Eb	1	1	1						3	2
Rothmannia engleriana	Re	1	2							3	2
Steganotaenia araliacea	Sa		3							3	2
Stereospermum kunthianum	Sk		2	1						3	2
Swartzia madagascariensis	Sm		2	1						3	2
Vangueria infausta	Vi	2	1							2	1
Multidentia crassa	Mc	2								2	1
Cassia abbreviata	Cb	1	1							2	1
Ormocarpum kirkii	Ok		1				1			2	1
Acacia nigrescens	Ar	2								2	1
Vitex payos	Vp	1								1	1
Combretum imberbe	Ci	1								1	1
Commiphora africana	Cf	1								1	1
Dalbergiella nyassae	Dy			1						1	1
Dombeya rotundifolius	Dr	1								1	1
Ficus sycommorus	Fy	1								1	1
Maytenus buchanannii	Mb	1								1	1
Maytenus senegalensis	Ms	1								1	1
Protea angolensis	Pn	1								1	1
Rhoicissus reivollii	Rr							1		1	1
Rhus longipes	Rl	1								1	1
Sclerocarya birrea	Sb	1								1	1
Securidaca longipedunculata	Sl	1								1	1
Turrea nilotica	Tn	1								1	1
Totals:	**76**	**219**	**652**	**631**	**465**	**236**	**134**	**42**	**18**	**2397**	**533**

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