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Characteristics and management potential of some indigenous firewood species in Malawi

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Abstract

Taking a case study from Malawi's Central Region, this paper identifies the locally important firewood species and discusses options for their management. The wood properties (moisture content and density) of 15 commonly used indigenous firewood species were determined and according to the fuel value index employed, the high grade firewoods were *Combretum apiculatum, Pericopsis angolensis* and *C. molle*. Supported by socio-economic, inventory and ecological data, the status (stocking and basic density) and coppice management of the preferred firewoods was then discussed. Whilst the high grade species had a low stocking in the woodland, their coppicing response was good, reaching a mean basal diameter of 4.4 cm and mean height of 3.3 m in 4 years. The paper proposes that these species be managed for domestic firewood on a coppice rotation of 5 years upwards and recommends that national policies for fuelwood production develop mechanisms for incorporating the rural woodland users into the management process. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

Firewood remains the dominant source of both domestic and commercial energy requirements for Africa's rural populations. It is used for food preparation, beer brewing, tobacco curing, brick firing, fish and meat smoking as well as heating and lighting in rural households. Substantial increases in human and bovine populations as well as decreasing forest areas have led to fuelwood shortages being reported in many countries. In Malawi, fuelwood shortages reportedly reached crisis levels as early as 1975 (McCall and Scutch, 1987). In the early 1980s, a World Bank review carried out by the Energy Studies Unit in Malawi suggested that around 800 000 ha of fast growing trees would have to be planted to meet estimated 1990 'deficits' of 8 million m^3, at a cost of well over US $360 million (French, 1986). By 1990, Malawi had only established 75 000 ha of fuelwood plantations (WRI, 1992) and in these, the necessary intensive plantation inputs were not always provided. This meant that the resultant productivity was often lower than expected, in some cases lower than that of

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the indigenous woodland it had replaced (Hardcastle, 1988). This illustrated the need for governments, struggling to cope with increasing fuelwood energy demands, to find lower cost alternatives to fuelwood plantations.

In most African countries indigenous woodlands still provide both urban and rural populations with by far the greatest proportion of their fuel requirements. If the existing firewoods from these woodlands could be identified and their productivity improved through silvicultural management, it is possible that alternative low-cost fuelwood sources could be developed. Capturing and enhancing the potential of these indigenous woodlands would be cheaper than plantations as well as more ecologically and culturally sound (Harrison, 1987). Furthermore, with the vast areas involved (Malawi is estimated to have between 40 000 and 46 500 km^2 of open and closed woodland (WRI, 1992; Shawa, 1993) which represents between 42 and 49% of the land area), it would also have a greater impact on the conservation of the environment and the provision of forest products and services.

This paper attempts to identify the management potential of a series of firewood species typical of the miombo of central Malawi. Whilst little is known of the impact of formal forest management on Malawi's indigenous woodlands (Lowore, 1993), the local people who are located amongst the woodlands already have detailed knowledge of their surrounding environment. Thus a case study approach was adopted, incorporating a survey of rural small-holders to examine firewood harvesting characteristics and identify desired firewood species. The study then established the status of these firewoods in the local landscape (in terms of stocking and basal area coverage) as well as their regeneration capacity, since studies working in miombo and elsewhere have found that domestic firewood collectors will locally exploit preferred species, leading to local scarcity (Chidumayo, 1979; Fleuret, 1980; Reid et al., 1990; Shackleton, 1993). As local scarcity increases, the number of species utilised increases as farmers diversify their product sources (Foley, 1985) and it is then that the most common species are more likely to be used first. After identifying the important indigenous firewood species using both physical and socio-economic criteria, along with an evaluation of their abundance and regenerative capacity, the paper presents options for their management.

2. Study site

The study is sited in north Kasungu, in Malawi's Central Region and is located at latitude 12°30′ S and longitude 33°30′ E. In order to gauge the status of firewood species under different harvesting intensities, it encompasses part of a protected Forest Reserve (Chimaliro) and the adjacent customary woodland. The woodlands are typical of the wetter plateau miombo (White, 1983), dominated by the species *Julbernardia paniculata* Benth and the genus *Brachystegia* (Anonymous, 1993).

The study area ranges from 1200 to 1600 m above sea level and has an annual rainfall of approximately 1100 mm. Chimaliro Forest was gazetted a Reserve in 1926 (Anonymous, 1926) and now covers 160 km^2 straddling Malawi's Kasungu and Mzimba districts (Anonymous, 1993). Lithosol soils occur in the Reserve while clay loam alluvial soils, with weathered ferrallitic soils in the lower lying areas, cover the neighbouring customary land.

The customary land adjacent to the southern boundary of the Reserve where the small-holder survey took place, is inhabited by just over 500 households resident in nine villages. The families collect firewood from the Reserve as well as from the 3.1 km^2 of woodlands found within village land (Lowore et al., 1993). The Reserve is state land and mainly used by villagers for the extraction of dead wood and non-wood products, the villagers' woodland is managed under customary law and is intensively utilised for its wood and non-wood produce.

3. Methodology

3.1. Selection of firewood species for analysis

Key informants – members of the community who were identified by their peers as being knowledgeable about firewoods and their qualities – were asked to list their preferred species. The use of key informants is a widely used procedure for the listing and ranking of tree species (e.g. Gumbo et al., 1990; Inglis, 1990; Scoones and Pretty, 1990). In this case, 12 informants were interviewed; six elderly women, four middle-aged women and two middle-aged men. The selection of species for physical analysis was made using the resulting list and information from earlier socio-economic studies in the same area (Lowore et al., 1993).

3.2. Firewood sampling procedure

For the analytical tests, wood samples were extracted from the Forest Reserve. Samples were taken from three separate trees of each species selected at random. Samples from each of three butt diameter classes – 1–5 cm, 5.1–10 cm and 10.1–15 cm – were taken from each tree. Each sample was labelled and packed in an air-tight bag until the first weight measurement was taken. All the samples were weighed within 5 h of cutting. Samples were taken during the month of October.

To investigate the characteristics of domestic firewood harvesting, the study co-operated with a sample of 35 households in the adjacent villages. The households were randomly selected from five of the nine villages. Over a 25-month period, these households were visited twice weekly by village-based enumerators and the firewood collection activities of the wife, husband (if present), one boy and one girl were recorded. Unused bundles were weighed to the nearest 0.5 kg using a spring balance and dimensions (butt circumference and length in cm) of a representative number of sticks was measured using a tape measure. This provided information on the type and size of firewood collected by the surrounding population.

3.3. Analytical tests on firewood properties

A quarter section from each wood sample was cut and used for the determination of wood basic density (kg m^{-3}), calculated by dividing its oven-dry mass by its saturated volume. The key informants indicated that cut firewood was rarely left to dry for more than 2 months prior to use, whereas air-dry moisture recordings for firewoods are commonly made up to 12 months after cutting (e.g. Tietema et al., 1991; McGregor, 1992). So as to mirror the typical air-dry moisture content at which fuel is used, the samples were in this case left to dry in the open for 8 weeks. Due to sampling problems, three species were sun-dried for only 5 weeks. Green and air-dry percentage moisture content on an oven dry weight basis was calculated for the quarter section and extrapolated for the sample as a whole.

A fuel value index (FVI) has been commonly used in the comparison of firewood species (e.g. Bhatt and Badoni, 1990, Bhatt and Todaria, 1992, Jain, 1992, 1993). In the index, the product of calorific value (kJ g^{-1}) and density (g cm^{-3}) is divided by the product of ash content (g g^{-1}) and water content (g g^{-1}). Calorific value was not estimated in this study, as suitable apparatus was not available within the country. However, since calorific values and ash contents of wood vary little (on an oven-dry mass basis) and the properties of density and moisture content are more important in assessing firewood characteristics (Davis and Eberhard, 1991) a more parsimonious index was used:

$$\mathrm{FVI} = \frac{\text{wood basic density kgm}^{-3}}{\text{\%moisture content (air-dry)}}$$

3.4. Woodland inventory

An inventory was undertaken in both the Forest Reserve and adjacent customary woodland to assess the current stocking and basal area representation of firewood species in the woody plant community. In both cases, sample plots were randomly located along transects running through the woodlands. Larger sample plot areas were used in the Reserve compared to those in the customary woodlands, due to the larger diameter classes and lower densities of enumerated stems in the Reserve. Thirty 20 × 50 m sample plots and thirty-three 10 × 10 m plots were placed in the reserved and customary woodlands, respectively. Due to the multi-stemmed nature of the trees, particularly in the customary woodlands, diameters were measured at stump height (0.3 m) as opposed to breast height (1.3 m). All trees over 5 cm diameter at stump height (dsh) were enumerated.

3.5. Coppice regeneration

Coppice regeneration for selected firewood species was assessed in a series of nine 0.125 ha (25 × 50 m) coppice plots set up in 1992 in the Forest Reserve at the study site. Height (m) and basal diameter (cm) of the leading coppice shoot per stool was taken along with the total number of coppice shoots per stool. A total of 261 trees were coppiced and enumerated. Diameters (at 1.3 m) of trees coppiced ranged from 5 to 45 cm and the study reports on summarised data from assessments undertaken 4 years after plot establishment.

4. Results and discussion of firewood characteristics

4.1. Preferred firewood species

When key informants were asked to name their desired firewood species, most provided a list of four or five. As Table 1 shows, preference was highly polarised, with *Julbernardia paniculata*, the species most commonly chosen as preferred. *Combretum* species are often cited as quality firewoods (Tietema et al., 1991; Shackleton et al., 1994). In this case, *C. apiculatum* and *C. molle* (the prevalent *Combretaceae* of the area) were highly rated by the respondents. *Pericopsis angolensis* is usually cited as construction material due to its durability (Campbell and du Toit, 1988), but according to the respondents it is also a good firewood. The range of species recorded as being amongst those preferred for firewood was limited to 14. According to Lowore et al. (1993) there are 24 species commonly used for firewood in this same area.

4.2. Local firewood harvesting practices

The household survey of firewood collection found that 89% of firewood harvested consisted of dry wood, mostly dry branches remaining from trees that had been cut previously for other purposes. Dry, dead wood represented 8% of firewood collected. This natural (usually fallen) dead wood was rarely harvested from the customary woodland due to the area's intensive use but it was collected from the Reserve, (where Forestry Department regulations stipulate that only dead wood is supposed to be gathered). Only 3% of firewood was collected in a green state. It was harvested from garden clearance operations and stored for use later during the busy agricultural season, by which time it would have dried out.

Firewood samples taken during the study revealed that headloaded firewood was generally 3–8 cm in butt diameter with a mean of approximately 5 cm. This finding is similar to other studies in Malawi which have indicated a modal size of between 3 and 5 cm butt diameter for domestic firewood (Coote et al., 1993; Lowore et al., 1993), and studies elsewhere that suggest domestic firewood demand peaks at sizes around 5 cm in diameter (Shackleton, 1993). However, the limits of sizes collected in the present study

Table 1
Firewood species identified by key informants and the number of times each mentioned as being amongst those preferred

Species		Frequency of preference
Botanical name	Vernacular name (Tumbuka)	
Julbernardia paniculata Benth.	Mtondo	9
Combretum apiculatum Sond.	Mulama	5
Acacia amythethophylla Steud. ex A. Rich	Chitongololo	4
Combretum molle R. Br. ex Don.	Kalama	4
Pericopsis angolensis van Meeuwen	M'wanga	4
Brachystegia floribunda Benth.	Mvukwe	3
Brachystegia spiciformis Benth.	Mpapa	3
Bauhinia thonningii Schum.	Msekese	2
Brachystegia boehmii Taub.	Chiyombo	2
Brachystegia longifolia Benth.	Chitowe	2
Brachystegia utilis Burtt Davy and Hutch	Kavwenje	2
Parinari curatellifolia Planch ex Benth.	Muula	2
Pseudolachnostylis maprouneifolia Pax.	Msolo	2
Uapaca kirkiana Muell. Arg.	Musuku	2

Table 2
Mean firewood dimensions collected by household members in study area and collection frequencies in 35 households over 25 months

Household Member	Firewood-type[a]		
	Swatu	*Nkhuni*	*Vigodo*
Wife			
L	1.54	2.47	2.24
D	3.5[a]	5.8	12.0
n	488	1986	61
Girl			
L	1.66	2.41	2.31
D	3.2	5.6	14.9
n	213	557	11
Husband			
L	0.90	2.63	2.17
D	3.8	6.3	15.1
n	10	183	150
Boy			
L	2.01	2.38	2.45
D	3.4	5.9	19.7
n	24	186	88

L, length (m); *D*, butt diameter (cm); *n*, frequency.
[a]Significant variation in diameter between firewood-types ($p \leq 0.01$).

ranged from greater than 2 cm to less than 25 cm in diameter and a closer inspection discovered the existence of a diameter-related firewood selection criterion (Table 2 and Fig. 1).

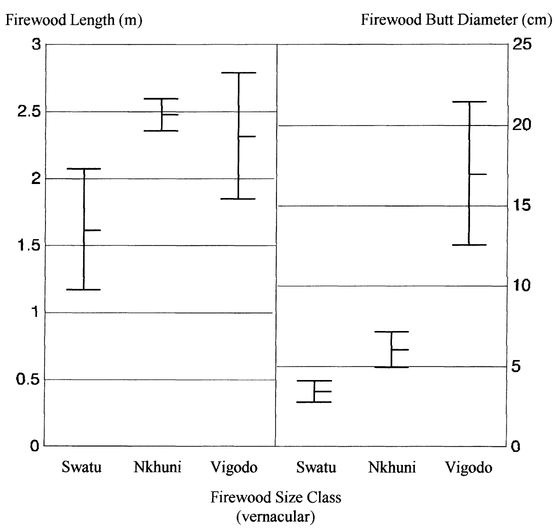

Fig. 1. Dimensions of local firewood size classes: mean and 95% confidence intervals.

The smallest size class of firewood known locally as '*Swatu*,' was used as kindling and for short duration cooking requirements. '*Nkhuni*' firewood was the most common type and used for most domestic cooking purposes. '*Vigodo*' was used for light industrial purposes such as tobacco curing, brick firing and beer brewing. Whilst butt diameters of the three firewood-types showed definite diameter classes, there was no significant variation in length of a firewood piece ($p > 0.05$) implying that it was less important in determining firewood-type (Fig. 1). The mean diameter within each firewood-type harvested remained consistent, varying little between household members (Table 2).

It is widely recognised that in most African societies women are the main collectors of firewood for domestic use (Williams, 1992) and in the Chimaliro villages this is no exception (Table 2). The results imply a gender bias in firewood-type harvested: women and girls collect most of the smaller size classes ('*Swatu*' and '*Nkhuni*') but very little of the larger material ('*Vigodo*'), which is left for the men and boys. It was found that women usually used small tools (such as machetes), and when cutting firewood lopped branches they could reach instead of felling whole trees. Thus the diameter class they harvested was limited by the tools used. Diameter was further constrained by the transport mechanism employed by women – usually the headloaded bundle, and by its utility – most firewood collected by women being used under the traditional 3-stone fire. Males had access to axe and oxen power which enabled them to harvest and transport the larger *Vigodo* as well as *Nkhuni*. Such gender-related attributes of harvesting will be discussed further in relation to firewood management.

4.3. Wood basic density

The wood basic densities calculated for the sample species in this paper (Table 3) are generally low compared to those of other studies in the region (Goldsmith and Carter, 1981; Chapola and Ngulube, 1989; Lowore et al., 1993). This differential may be explained by the fact that the present tests were made on small dimension material, that is, material commonly used by villagers for firewood, which may be less dense than the timber sizes used in the other studies. *Brachystegia floribunda* excepted, the five

Table 3
Wood properties of 15 commonly used firewood species and their corresponding FVI

Species	Basic density kg m^{-3}		% Moisture green[a]		% Moisture air-dry[b],[c] 8 weeks		Fuel Value Index	Ranking by index
	Mean	SE	Mean	SE	Mean	SE		
Combretum apiculatum Sond.	724	10.6	56.91	1.3	37.61	0.2	19.25	1
Pericopsis angolensis van Meeuwen	758	17.0	65.11	2.4	45.14[d]	2.2	16.79	2
Combretum molle R. Br. ex Don.	669	14.0	63.74	1.0	41.45	1.4	16.13	3
Parinari curatellifolia Planch ex Benth.	597	11.0	68.50	1.0	42.09	2.0	14.18	4
Brachystegia floribunda Benth.	676	6.0	70.07	0.8	50.07	1.2	13.50	5
Uapaca kirkiana Muell. Arg.	570	6.6	69.25	1.4	42.63	1.6	13.37	6
Julbernardia paniculata Benth.	644	11.3	70.83	(1.9)	51.44	2.8	12.52	7
Bauhenia thonningii Schum.	595	7.0	71.33	0.8	48.96	1.5	12.15	8
Acacia amythethophylla Steud. ex A. Rich.	666	19.3	72.79	1.5	59.42[d]	4.1	11.20	9
Senna singueana Lock ex Del.	602	5.6	73.06	0.8	55.70[d]	2.0	10.81	10
Brachystegia longifolia Benth.	548	12.3	71.18	1.1	52.33	1.4	10.47	11
Brachystegia utilis Burtt Davy and Hutch.	598	7.0	73.61	1.5	57.65	2.2	10.37	12
Pseudolachnostylis maprouneifolia Pax.	595	7.0	74.47	1.7	58.28	2.7	10.21	13
Brachystegia spiciformis Benth.	579	7.3	77.55	0.9	62.52	1.3	9.26	14
Brachystegia boehmii Taub.	598	8.3	79.41	1.7	65.99	2.5	9.06	15

[a]Significant variation in green moisture content between species ($p \leq 0.01$).
[b]Significant variation in air-dry moisture content after 8 weeks between species ($p \leq 0.01$).
[c]No significant difference in rate of moisture loss between species after 8 weeks ($p \leq 0.05$).
[d]At 5 weeks.

most preferred species (as listed in Table 1) recorded the five highest basic densities. According to the key informants, the higher density species produced firewood providing longer lasting embers, which were much valued.

4.4. Percent moisture content

Moisture content was an important factor in firewood preference as it affected the weight of wood when transported, fire temperatures and ignition times. Green moisture content varied from 56.9% for *C. apiculatum* to 79.4% for *B. boehmii* (Table 3). The two *Combretum* species had the lowest air-dry moisture contents at under 42% with *B. boehmii* and *B. spiciformis* the highest at over 60%. After 8 weeks of air-drying, the moisture content had dropped between 13.3% for *B. boehmii* and 26.6% for *U. kirkiana*. The rate of moisture loss between species was relatively even, there being no difference in percent moisture loss (at $p \leq 0.05$). This observation meant that the difference in percent green moisture content (at $p \leq 0.01$) between species was retained in the air-dry state. Furthermore, after the short drying period, the air-dry moisture content was still influenced by the green moisture content ($r^2 = 0.78$, $p \leq 0.01$). In cases such as this, seasonal differences in green moisture contents are likely to affect species choice as well as the quality and quantity of wood used. However, it was not possible to ascertain seasonal differences in firewood use from this study as the samples were all collected at once.

4.5. The fuel value index

The preferred firewoods – *C. apiculatum*, *P. angolensis*, and *C. molle* – were accorded the highest fuel value index (FVI) scores (Table 3). That *P. angolensis* gained such a high FVI score despite its shorter drying period implies that it is very efficient as a firewood. However, the most preferred species, *J. paniculata*, scored poorly on the FVI. Comparing the ordering produced by the easily derived FVI and the key informant ranking of preferred species suggests that the basic properties of FVI represent the most important characteristics required of woods for the common end-uses and as such it is a useful tool for comparisons of domestic firewood species. However, Abbot et al.

(1997) assert that rural people are very discerning about their firewood requirements and that there are characteristics other than basic properties that need to be considered, such as flammability, flame brightness, and flaming period. For example, lower density woods ignite more easily but burn more quickly whilst extractives in the timber affect flame brightness and temperature. These socially defined properties play a role in shaping rural peoples' perception of acceptable firewood qualities and may help to explain the high social preference for *J. paniculata*.

5. Status and management potential of preferred firewood species

5.1. Representation of firewood species in the study area

The representation of the common firewood species greater than 5 cm dsh in the Forest Reserve (total basal area 15.7 m^2 ha^{-1}, stocking 700 stems ha^{-1}) and customary woodland (total basal area 12.1 m^2 ha^{-1}, stocking 1470 stems ha^{-1}) is shown in Table 4. Except for the sacred groves and protected riparian strips, the customary land woodlands mainly comprise short-wooded fallow of between 1 and 20 years old. Stocking is more dense than the Forest Reserve which, with a mature overhead canopy, has less regenerating under-storey.

In the Forest Reserve the *Brachystegia* species, *J. paniculata* and *P. angolensis* dominate the canopy. The rest of the preferred firewoods are either part of the under-storey or are suppressed at the shrub layer due to overhead shading. Taken together, *J. paniculata* and the *Brachystegia* species account for about 52% of the stocking and 70% of the basal area. The remaining firewood species, including the most preferred, account for only 15% of the stems and 14% of basal area.

The customary land has a higher species diversity (66 species compared to the Reserve's 43 species), due in part to its more varied structure and age which have allowed invasive and pioneer species to become established. However, the most common canopy species in the customary woodland remain *J. paniculata* and the *Brachystegia* species. Together they represent 40% of the stocking, with the other firewood species account-

Table 4
Status of firewood species in reserved and customary woodland at study site

Species	Forest Reserve				Customary land woodland			
	g[a] ha^{-1}	% G[b]	n[c] ha^{-1}	% N[d]	g ha^{-1}	% G	n ha^{-1}	% N
A. amythethophylla	0.146	0.93	4	0.6	–	–	–	–
B. thonningii	0.069	0.44	3	0.4	0.064	0.52	21	1.4
B. boehmii	2.487	15.70	64	9.1	0.440	3.60	63	4.2
B. floribunda	1.519	9.64	49	7.0	0.628	5.18	73	4.9
B. longifolia	0.713	4.52	57	8.1	–	–	–	–
B. spiciformis	0.436	2.76	11	1.5	0.883	7.28	12	0.8
B. utilis	2.441	15.49	72	10.2	2.270	18.7	100	6.8
C. apiculatum	0.002	0.01	1	0.1	0.013	0.11	3	0.2
C. molle	0.200	1.27	7	1.0	0.450	3.70	9	0.6
J. paniculata	3.390	21.51	116	16.5	2.760	22.7	351	23.8
P. curatellifolia	0.217	1.38	12	1.8	0.90	7.42	79	5.3
P. angolensis	1.010	6.40	30	4.3	0.011	0.09	24	1.6
P. maprouneifolia	0.104	0.65	11	1.5	0.333	2.74	39	2.6
S. singueana	0.011	0.07	2	0.2	0.128	1.05	24	1.6
U. kirkiana	0.383	2.43	37	5.3	0.985	8.12	51	3.4

Stems greater than 5 cm dsh.
[a] g, Basal area (m^2) of species sample.
[b] G, total basal area sampled.
[c] *n*, Frequency of species sample.
[d] *N*, Total stocking sampled.

ing for almost 17% of the density and 24% of basal area representation. However, the edible fruit-bearing tree species *P. curatellifolia* and *U. kirkiana* are more common in the customary land. This may be due to edaphic differences or to the fact that these species are traditionally spared the axe when the woodland is cleared (Wilson, 1990; Packam, 1993).

Comparison of species representation in customary and reserved woodlands implies that the preferred firewoods have maintained their status within the heavily utilised customary woodland community. This suggests that these species are able to regenerate adequately despite continued cutting – a capacity noted in other studies of miombo regeneration (e.g. Tuite and Gardiner, 1994). It can also be argued that the socio-economics of firewood harvesting, as indicated by the results of the firewood collection survey, affect the status of firewood species in the woodland. Much firewood is collected by women and their head-loaded firewood is commonly collected as a by-product of activities such as pole cutting. The commonly used firewood species then, are those commonly cut as poles or for other wood uses such as timber and tool handles, and not necessarily those specifically desired for firewood. In this rural community, the extraction of headloaded firewood by women (who mainly collect the smaller '*Nkhuni*' and '*Swatu*') is likely to have a lower direct impact on the woody community than the other wood-harvesting activities commonly undertaken by men.

5.2. Coppice regeneration of firewood species

Although *J. paniculata* is the most densely stocked firewood species in both the Forest Reserve and customary woodland, coppice growth rates are not vigorous (Table 5). Four years after coppicing, the species had produced on an average of six shoots per stool, attaining mean shoot diameter of 3.2 cm and a mean shoot length of 1.6 m. Robertson (1984) notes that whilst coppice and sucker production in this species is weak, seed production is prolific and the abundance of *J. paniculata* in both the reserved and customary woodlands implies that its regenerative capacity is sufficient to sustain the population at current rates of extraction.

Although the other preferred species are less common, Table 5 indicates that coppice growth is more vigorous. Both *P. angolensis* and *P. maprouneifolia* initially produce a large number of small shoots, *A. amythethophylla* and the two *Combretum* species produce fewer, more vigorous, shoots. The main coppice shoots of the *Combretum* species, *A. amythethophylla* and *B. thonningii* attained an average height of 3.3 m in 4 years with a mean diameter reading of 4.5 cm and it is possible these species

Table 5
Four-year coppice regeneration for selected species at Chimaliro Forest Reserve

Species	Mean no. of coppice		Mean coppice height		Mean coppice shoot	
	Shoots	SE	m	SE	Basal dia. (cm)	SE
Acacia amythethophylla	3.6	0.556	3.44	0.128	4.67	0.383
Bauhinia thonningii	11.0	8.100	3.10	0.106	5.66	0.384
Brachystegia boehmii	5.6	0.466	1.71	0.107	4.18	0.264
Brachystegia floribunda	8.1	0.605	2.38	0.099	4.55	0.219
Brachystegia longifolia	6.6	2.012	2.00	0.138	4.80	0.559
Brachystegia spiciformis	7.9	1.222	3.06	0.170	4.91	0.289
Brachystegia utilis	7.0	0.519	2.42	0.079	4.56	0.171
Combretum apiculatum	2.2	0.550	3.36	0.328	4.19	0.503
Combretum molle	3.5	0.494	3.55	0.445	3.75	0.544
Julbernardia paniculata	6.5	0.357	1.62	0.044	3.27	0.096
Pericopsis angolensis	8.9	1.065	1.94	0.097	3.92	0.289
Pseudolachnostylis maprouneifolia	8.9	0.837	2.38	0.141	4.56	0.352
Uapaca kirkiana	6.8	0.493	1.74	0.053	4.60	0.141

Mean coppice height and basal diameter derived from tallest shoot per stool.
SE, standard error.

could produce domestic firewood of *Swatu*- and *Nkhuni* types in 5 years.

5.3. Management options for firewood species in rural Malawi

As regeneration of miombo woodlands through vegetative, as opposed to seedling, regrowth is more productive, in the short term at least, management systems for wood products of small (non-timber) dimensions have historically been based on coppice or coppice with standard systems (e.g. Wigg, 1953; Hursh, 1960; Edwards, 1982; Chidumayo, 1987; Coe, 1992; Lowore and Abbot, 1994). These systems were usually applied with the intention of producing a single or primary output (often poles or wood fuel). For firewood production, Fanshawe (1959) proposed a 40-year rotation whilst Wigg (1953) recommended 20 years. Siddle (1995) calculated that the maximum mean annual increment was reached between 30 and 35 years for *J. paniculata* coppice on a good site and despite the rather poor vigour of coppice, indicated that *J. paniculata* could be managed for domestic and industrial firewood on a 10- and 22-year coppice rotation, respectively.

However, miombo provides much more than just firewood to local populations and management must reflect the multiple utility of the woodlands. As early as 1960, Hursh (1960) recognised rural peoples' multiple requirements and suggested the production of firewood and small poles on a 15-year coppice cycle with a lower number of the preferred pole species reserved on a 30-year rotation for large poles. But, management for firewood production at a local community level requires a system providing faster returns. Similarly it must be simple enough for local people to use. By investigating the current harvesting patterns of woodland users, this study indicates that local people exercise considerable discretion in species and size choice to suit a particular end-use. The species and size-specific manner in which miombo is used suggests that woodland management be based on species as the basic management unit and this has been supported by other studies (e.g. Shepherd, 1992; Sow and Anderson, 1996).

A selective coppice system, as part of a multi-resource management regime is one potential strategy for domestic firewood production in miombo. Coppice stools could be thinned as shoots attained a prescribed size limit (possibly about 5 cm basal diameter according to this study) allowing the preferred species such as *A. amythethophylla*, *B. thonningii*, *P. angolensis* and the *Combretum* species to be managed on a coppice rotation as short as 5 years for the production of firewood. The *Brachystegia* and other common species, including *J. paniculata*, could be grown on a longer 10–15-year rotation for poles or large '*Vigodo*' firewood. The lop and top from pole harvesting would provide further fuel resources and pole stems of poor form could be culled and used for firewood, since a managed coppice stem is likely to be straighter (Hursh, 1960). Post-harvest coppice stool mortality can reach 30% (Chidumayo, 1989) but this is concentrated on the larger stems: mortality of coppiced stems in miombo is almost 100% above 40 cm dsh, but almost zero below 10 cm (Edwards, 1982). Size-related mortality would therefore diminish after the introductory conversion felling. Initially, replacement would probably come from the large bank of suppressed seedlings existing in the shrub layers and released from competition, but with successive rotations, the proportion of regeneration would shift towards sucker and coppice regeneration. The stocking of the high grade firewoods could be augmented by severing lateral roots to promote suckering and/or by leaving standards of selected species as mother trees. Such a system would provide stems harvestable by women – the main domestic firewood collectors – in terms of accessibility, size and species choice. It would at the same time maintain, on a longer rotation, stems for poles and firewood for light industrial purposes, that is, the material most commonly harvested by men.

6. Conclusions

According to Poynton (1984), species being grown for firewood should be:

1. well-suited to the local climate, unless grown under irrigation;
2. capable of adapting to the conditions of the site;
3. cheap and easy to establish;
4. of vigorous growth;
5. amenable to management in woodlots;

6. able to regenerate naturally;
7. possessed of good burning properties.

Under these criteria, there would seem potential for Malawi's miombo woodlands to be managed for firewood. This is particularly the case on difficult sites – those with poor soils and/or low rainfall – where management of natural woodlands can provide a practical alternative to afforestation for fuelwood production. The contribution of miombo to rural energy needs is already acknowledged in Malawi and elsewhere in the region (e.g., Dewees, 1995, 1996). But, with growing populations and increasing demands on the wooded resource, it is becoming more important that the countries of the miombo biome develop options for its management and mechanisms for incorporating the rural woodland users into the management process.

The study showed the micro-environment specificity of rural firewood management, which justified the use of a case study approach and a multi-disciplinary methodology in examining the potential options for firewood production. This enabled a valuable insight into the socio-economics of firewood harvesting, indicating that the key informants had a detailed knowledge of firewood species and showed the existence of a locally determined typology, which formed the basis for a size and species-specific selection system.

This implies that the potential of systems for rural wood fuel production will only be realised once it is acknowledged that it is the local users who have the wide technical knowledge required for effective management. This emphasises the need for national policies to incorporate locally derived management technologies in the firewood planning process and, by using findings from physical, socio-economic and ecological investigations into indigenous firewoods, this paper has shown how locally appropriate management options for firewood production can be developed.

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