Changes in fuelwood use and selection following electrification in the Bushbuckridge lowveld, South Africa

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Abstract

Fuelwood is the primary energy source for domestic purposes throughout the developing world, in both urban and rural environments. Due to the detrimental impacts of biomass use on human and environmental health, many governments have sought to reduce its use through provision of potentially cleaner energies, of which electricity is the dominant form. Yet there are surprisingly few studies of changes in fuelwood use following the introduction of electricity, especially in rural areas of Africa. This paper reports on a longitudinal study of fuelwood use, using identical approaches, in five rural villages in the Bushbuckridge region of South Africa, spanning the period over which electricity became widely available. Almost a decade after the introduction of electricity, over 90% of households still used fuelwood for thermal purposes, especially cooking, and the mean household consumption rates over the 11-year period had not changed, even with a policy of 6 kWh per month of free electricity. The proportion of households purchasing fuelwood had increased, probably in response to a number of factors, including (i) increased fuelwood scarcity in the local environment as reflected by increased fuelwood collection times, changes in fuelwood species preferences, and ranking of scarcity by local collectors, and (ii) increases in the price of fuelwood well below that of other fuels and the prevailing inflation rate. Overall, there was an increase in the number of species harvested over the 11-year period. The implications of these findings for rural energy provision are discussed.

1. Introduction

Throughout the developing world biomass energy is the primary source of energy for domestic use. The most widely used form of biomass is fuelwood, although in areas of natural or human imposed scarcity of wood, other biomass forms such as crop residues and dung become more prevalent (e.g. Bhatt and Sachan, 2004; Shackleton et al., 2004). Biomass as a source of energy is also enjoying renewed interest in the developed world as a renewable energy (e.g. Bernades et al., 2003).

In sub-Saharan Africa, fuelwood and charcoal are the staple energy forms for most rural as well as many peri-urban and urban communities. They are also used by small-scale businesses such as bakeries, brick-making and fish-smoking (Sheya and Mushi, 2000; Brouwer and Falcão, 2004). Work in Zimbabwe, Kenya, Mozambique, Tanzania and South Africa, to name a few, has shown that the vast majority of rural households rely extensively upon fuelwood as their basic energy source (Sheya and Mushi, 2000; Vermeulen et al., 2000; Kituyi et al., 2001; Brouwer and Falcão, 2004; Shackleton et al., 2004) and that this has changed little over the last few decades, despite increasing population pressures and changing socio-economic and environmental profiles. In many instances it has been argued that the widespread use of fuelwood is linked to a number of environmental problems, including deforestation, biodiversity loss, climate change and land degradation (e.g. Sankhayan and Hofstad, 2001). The presence of these environmental problems at any given site may have detrimental consequences for livelihood security and sustainability. These may be manifest as a decrease in human well-being that can be measured in social and economic terms, such as longer fuelwood collection times and opportunity costs (e.g. Brouwer et al., 1997), localised loss of useful fruit species (e.g. Shackleton, 1993), increased cash needs to purchase alternatives (e.g. Griffin et al., 1992), and reduced cooking times and hence poorer nutrition (e.g. Brouwer et al., 1989). However, the relative contribution of fuelwood use to environmental decline has been questioned, especially in terms of biodiversity loss, deforestation and land degradation (Dewees, 1989; Benjaminsen, 1997; Sullivan, 1999; Nagothu, 2001). It has been shown in many cases that fuelwood use is usually only a minor contributor to these problems, except where urban demand is significant (e.g. Hosier and Milukas, 1992; Luoga et al., 2000).

Given the changing socio-economic and environmental contexts in which rural communities operate, it is important to develop a predictive knowledge of how patterns of fuelwood use change over time. This is especially so in relation to the increasing availability of electricity, particularly in southern Africa. For example, in South Africa the post-apartheid government developed energy policies designed to widen access to adequate and affordable energy services for urban and rural households (Davis, 1998). The policies were also aimed at providing cleaner and safer forms of energy for low-income households (Spalding-Fecher and Matibe, 2003). The Department of Mineral and Energy Affairs embarked on an accelerated electrification programme in most rural areas of South Africa (DME, 1998). Because much of the population of rural South Africa is located in areas far from the current and anticipated electricity grid connections, off grid renewable energy resources, particularly photovoltaic, also played a role in the electrification exercise. In the period 1994–1999, about 2.8 million households were connected to the national electricity grid increasing the level from 36% in 1994 to 68% by the end of 1999 (Kotze, 2001).

The impacts of the introduction of electricity, in the face of declining fuelwood stocks in some regions, have been reported by a number of authors. However, the majority of these studies are based on observed differences between electrified and unelectrified households (e.g. Davis, 1998), and longitudinal studies with a clear baseline before electrification are limited (e.g. Vermeulen et al., 2000; Madubansi, 2003). The few that are available are restricted to urban and peri-urban communities (White et al., 1997; Palmer, 1999), and focus on the amount of wood used with limited attention to collection dynamics and changing species preferences. There is a need, therefore, to determine changes in consumption rates and harvesting patterns after the introduction of electricity based on quantitative data from before and after electrification in a longitudinal survey of the same area or same households. In this way the results would not be confounded by differences in household wealth as experienced in latitudinal studies (Davis, 1998). Thus, within the context of the above, the objective of this study was to investigate the changes in patterns of fuelwood use in the Bushbuckridge district between 1991 and 2002 based on a longitudinal study using the same survey instrument of five villages spanning the period during which electricity was introduced.

2. Study area

The study was conducted in five villages in the Bushbuckridge district in the southernmost section of the Limpopo Province, South Africa. The settlements were the same as those for the 1991 study of Griffin et al. (1992), namely Athol (24°43′S 31°21′E), Okkerneutboom (24°44′S 31°13′E), Rolle (24°44′S 31°13′E), Welverdiend (24°35′S 31°20′E), and Xanthia (24°50′S 31°09′E). These settlements are spatially dispersed and represent a range from smaller, isolated settlements (Athol, Welverdiend) to larger, more closely settled settlements lying adjacent to major transport routes (Okkerneutboom, Rolle).

The region is characterised by shallowly undulating terrain with an altitude that is generally less than 600 m above sea level (Banks et al., 1996), and experiences hot, humid summers and mild winters. The mean annual temperature is approximately 22 °C and increases from southwest to northeast. The mean annual rainfall ranges between 500 and 700 mm and is concentrated in the summer season from October to April (Shackleton et al., 1994). The vegetation is broadly classified as semi-arid savanna and is characterised by a mixture of trees, shrubs and grasses. Dominant tree genera are *Acacia*, *Albizia*, *Combretum*, *Grewia*, *Sclerocarya* and *Terminalia*.

Human population densities range between 200 and 350 people km^{-2}. Mean household size is approximately 6–7 persons. These settlements are typical of the neglected and underdeveloped settlements in many other former ‘homelands’ established under the segregationist apartheid system in South Africa (Pollard et al., 1998). Thus, there is inadequate infrastructure, high unemployment, and a high household dependency on pensions and remittances from migrant workers. Consequently, households engage in a diverse array of informal activities to support their livelihoods, including arable agriculture, home-gardens, livestock husbandry, collection of natural resources (e.g. fuelwood, thatch grass, medicinal plants), casual work, migrant labour, and small-scale enterprises (Pollard et al., 1998).

The majority of households in the region depend on biomass fuels as their primary source of energy, especially fuelwood (Madubansi, 2003). Collected fuelwood accounts for a large proportion of the total fuelwood used in the region although some households buy it from local vendors. Other fuel types used include paraffin, candles, gas, coal, dry cell batteries, dung, lead acid batteries and some electricity (Griffin et al., 1992; Madubansi, 2003). At the time of the 1991 survey electricity was available in two of the study villages (Okkerneutboom and Rolle), but was not distributed within the villages, thereby making connection fees expensive and beyond the reach of most of the villagers. Less than 1% of households in these two villages had electricity in 1991 (Griffin et al., 1992). With the democratic transition in the early 1990s, the new South African government embarked upon a major electrification drive (between 1993 and 1996 in the study area). Consequently, over two-thirds of the households in the region as a whole now have electricity. Of the five study villages, only Athol currently has no access to the national electricity grid. For the other four villages over 95% of households have electricity other than Rolle where the figure is 88% (Madubansi and Shackleton, in press).

3. Methods

Since the current research was a follow-up study, it used the same methods as in the 1991 study (Griffin et al., 1992). A structured interview schedule is ideal for longitudinal studies as it limits flexibility (Frey and Fontana, 1991). It ensures that the same style and approach is followed to gather data from surveys conducted at different times. Therefore, the current study used the same structured interview schedule that was used in the 1991 study (Griffin et al., 1992) to gather data on household fuel use, preferences and socio-economic status. The second author was a member of both the 1991 and 2002 research teams. All the interviews were conducted in the local language (XiTsonga). Where possible, the person who did most of the cooking and housework in the household was interviewed as he or she would best know the types and quantities of fuels used. In the absence of such individuals, we interviewed the household head or another adult member. The interviewee frequently conferred with other family members in answering some questions, particularly those related to costs and quantities of the different fuel forms.

Estimates of fuelwood consumption were made based on the respondent's estimates of their daily fuelwood use. The respondents were asked to estimate the amount of fuelwood used on a daily basis and this was weighed and recorded. During the 1991 survey, the accuracy of this method was checked by monitoring daily fuelwood use over two weeks at ten households in Welverdiend village, which was then compared to their previous estimates of use. The household consumption data from the carefully monitored samples were not significantly different from the respondent's estimates of household fuelwood consumption in the same households (Banks et al., 1996). We assumed the same would apply in 2002. The 2002 survey was conducted during the equivalent season as the 1991 survey (late winter/spring) to avoid introducing potential seasonal differences.

Using 1:10 000 aerial photographs (1997) settlement boundaries were defined and household plots demarcated and numbered, which were then used to select an entirely random sample, as was also done in 1991. The total number of households sampled was 399 in 2002 (representing a 13.6% sample intensity), compared to 356 in 1991, which more than compensated for anticipated population growth during the intervening period. The numbers per settlement were 71 in Athol (299 households), 83 in Okkerneutboom (830 households), 80 in Rolle (640 households), 80 in Welverdiend (530 households) and 85 in Xanthia (643 households). Like in the previous study, a number of conventions were followed if, for some reason, we were unable to interview a suitable respondent at a sample household. In the first instance we revisited that house within seven days of the initial visit. If a suitable occupant still was not available, that household was removed from the sample list and replaced by another randomly selected household. The survey instrument covered all energies and fuels used by the household, but this paper focuses on fuelwood. In terms of fuelwood we considered amounts used, purposes, how obtained, collection times and species preferences at each of the two periods, along with household data such as size, education, employment and income.

3.1. Data analysis

Data from the interview schedules were collated and analysed using Microsoft Excel (Excel 2000) and Statistica (Statistica 6.0). Discrete variables were summarised by determining the frequency of each code within the question. Frequency analysis was undertaken for each settlement separately. Summary statistics were calculated for all numeric variables. Normality for all the data was tested using the Shapiro and Wilks test. Other measures of distribution, for example skewness and kurtosis were also examined. After inspection of these data, it was decided that the arithmetic mean was the best measure of central tendency for the data. Since many of the numeric variables failed the assumption of normality and homogeneity of variances, a Mann–Whitney *U*-test was used to compare the continuous data from the two surveys (1991 and 2002) for the whole region. However, when comparing the means across the individual settlements, the data were transformed using the log transformation to stabilise the variances and an ANOVA was then used to compare the means. Percentage data were arcsine transformed and analysed via χ^2 analysis. The normal per capita consumption was used, for which each person in the sample, regardless of age or gender, represents one unit. The currency exchange rate was US$1=R3.70 and R12.50 in 1991 and 2002, respectively, and is currently about R6.10. The mean diversity of preferred species used per village was determined using Simpson's diversity index calculated as

$$S=1/\sum(p_i)^2, \qquad (1)$$

where p_i proportion of households preferring each species.

4. Results

4.1. Use of fuelwood

There was an insignificant decrease in the mean percentage of households using wood from 97% in 1991 to 94% in 2002 (χ^2=1.05; p>0.05). Okkerneutboom and Rolle reported the highest decrease. Mean consumption rates for all the settlements were 40.5 and 44.9 kg per capita per month in 1991 and 2002, respectively (Table 1), which were not significantly different (Z=0.9; p>0.05). Across all settlements mean consumption of wood was reported at 323.9 and 317.2 kg per household per month in 1991 and 2002, respectively. There were no differences (F=0.099; p>0.05) between settlements with respect to the magnitude of change in consumption between the two periods.

Table 1
Household monthly fuelwood consumption rates (mean ± SE) in five rural villages in 1991 and 2002

Settlement	% HH using fuel		kg per capita per month		kg per HH per month	
	1991	2002	1991	2002	1991	2002
Athol	99	100	42.1 ± 2.4	46.5 ± 2.7	309.3 ± 22.3	321.0 ± 19.6
Okkerneutboom	96	88	31.3 ± 2.3	38.4 ± 2.8	251.0 ± 17.5	270.7 ± 20.7
Rolle	96	89	37.5 ± 2.2	40.7 ± 2.8	306.2 ± 28.0	306.6 ± 20.6
Welverdiend	99	96	46.7 ± 2.1	45.4 ± 2.8	399.9 ± 27.2	331.1 ± 20.4
Xanthia	93	96	45.0 ± 2.6	53.8 ± 2.6	353.0 ± 22.5	358.6 ± 19.2
Mean	97	94	40.5 ± 2.3	44.9 ± 2.7	323.9 ± 25.5	317.2 ± 20.1
Significance	χ^2 = 1.05; p > 0.05		Z = 0.9; p > 0.05		Z = 0.4; p > 0.05	

In both years over 95% of respondents reported that the main use of fuelwood was cooking (Table 2). The second most common use in 1991, namely making a fire outside for warmth (71% of user households), had significantly (χ^2=92.4; p<0.001) decreased by 2002, to only 5% of users, all of whom were in Athol, the unelectrified settlement. Large decreases were also recorded amongst users in terms of using fuelwood to heat water for tea (χ^2=32.0; p<0.001) and for heating irons (χ^2=33.9; p<0.001). In comparison, the prevalence of heating water for washing using fuelwood increased from 23% of users in 1991 to 62% in 2002 (χ^2=31.1; p<0.001).

Table 2
Main use of fuelwood in households across five villages in 1991 and 2002

Other uses	Year	Settlement					Mean	Significance
		Athol	O'boom	Rolle	Welv'd	Xanthia		
Cooking	1991	100	100	99	94	100	99	$\chi^2 = 1.9$
	2002	96	92	100	94	98	96	$p > 0.05$
Outside fire for warmth	1991	96	49	73	65	71	71	$\chi^2 = 92.4$
	2002	24	0	0	0	0	5	$p < 0.001$
Heating tea water	1991	90	46	86	32	91	69	$\chi^2 = 32.0$
	2002	0	16	28	48	52	29	$p < 0.001$
Heating water for washing	1991	33	10	30	4	36	23	$\chi^2 = 31.1$
	2002	82	58	62	48	58	62	$p < 0.001$
Ironing	1991	45	16	29	30	23	29	$\chi^2 = 33.9$
	2002	0	0	0	0	0	0	$p < 0.001$

Data are percentage of users.

4.2. Purchased wood

The mean proportion of households purchasing wood was relatively constant (χ^2=0.4; *p*>0.05) between 1991 and 2002, 27% and 31%, respectively (Table 3). Although insignificant in percentage terms, an increase was observed in four of the five settlements, indicating a relatively uniform trend. In both years Okkerneutboom and Rolle had the highest percentage of households purchasing wood, which correlates with their large population size and hence probable wood scarcity in the area. Residents at Rolle also had the highest mean monthly household income (R1 360), but those at Okkerneutboom had the lowest (R958), and so the higher occurrence of wood purchases at these two villages cannot be correlated with household income relative to the other villages. The mean per capita consumption per month of purchased wood remained unchanged between the two survey periods; 19.9 kg in 1991 and 20.1 kg in 2002 (*T*=0.04; *p*>0.05). In both years more than 60% of the respondents who did not buy wood saw no need of doing so because they could still collect it for free (Table 4). Nevertheless, the percentage of respondents with this view had greatly reduced by 2002 (χ^2=22.3; *p*<0.001) indicating that there was an increasing number of people who no longer considered fuelwood to be a free commodity. This perception was lowest in Okkerneutboom and Rolle. In comparison, the proportion of non-users citing expense as a reason for not buying fuelwood had increased from 4% in 1991 to 27% in 2002 (χ^2=20.2; *p*<0.001). A small proportion of non-users each time cited the difficulty of finding traders as a reason for not using purchased wood.

Table 3
Prevalence of use, monthly consumption rates and unit price of only purchased fuelwood (mean ±SE) in five villages in 1991 and 2002

	Year	Settlement					Mean	
Significance		Athol	O'boom	Rolle	Welv'd	Xanthia		
% of hh using purchased fuelwood	1991	1	68	34	19	15	27.4	$\chi^2 = 0.4$
	2002	8	63	48	20	16	31.0	$p > 0.05$
kg per capita per month	1991	0	32.6	36.4	16.6	13.7	19.9	$T = 0.4$
	2002	4.1	35.0	35.5	16.0	10.0	20.1	$p > 0.05$
kg per hh per month	1991		373.8±39.4	762.3±109.8	858.1±226.7	602.5±140.2	519.0±98.3	$Z = 1.7$
	2002	351.1±110.5	344.0±37.5	496.0±47.5	564.0±65.6	398.0±75.1	430.6±67.3	$p > 0.05$
Cost per kg (Rand)	1991		0.13±0.01	0.08±0.01	0.07±0.01	0.26±0.19	0.14±0.04	$Z = 1.0$
	2002	0.25±0.03	0.25±0.01	0.22±0.01	0.21±0.02	0.18±0.02	0.22±0.02	$p > 0.05$
	1991 equivalent	0.11±0.001	0.11±0.004	0.10±0.004	0.09±0.008	0.08±0.008	0.10±0.009	

Table 4
Reasons given for not buying fuelwood reported by non-users at five villages in 1991 and 2002

Settlement	Can collect for free		Too expensive		Difficult to find traders	
	1991	2002	1991	2002	1991	2002
Athol	100	78	0	18	0	0
Okkerneutboom	77	26	14	55	4	4
Rolle	92	48	0	38	0	5
Welverdiend	95	80	4	8	2	2
Xanthia	92	83	3	15	0	0
Mean	91	63	4	27	1	2
Significance	$\chi^2 = 22.3$; $p<0.001$		$\chi^2 = 20.2$; $p<0.001$		$\chi^2 = 0.34$; $p>0.05$	

Data are percentage of non-users.

4.3. Collected wood

Most of the fuelwood in the region is gathered free of charge from the surrounding environment, and thus, the majority of the households collected wood (Table 5): 78% in 1991 and 64% in 2002 (χ^2=4.8; p<0.05). The decline in the proportion of households collecting their own fuelwood mirrored the increase in those purchasing fuelwood, as well as a decline in fuelwood availability as measured through mean collection time. There was a significant increase in the time spent on fuelwood collection between 1991 and 2002, from a mean of 239±15 min per trip in 1991 to 268±21 min per trip in 2002 (Z=3.20; p<0.0001). The overall duration of a collection trip increased in all settlements, with the greatest increase at Okkerneutboom, and the least at Xanthia (F=12.05; p<0.0001).

Table 5
Duration of fuelwood collection trips and time spent monthly per household on fuelwood collection for five villages in 1991 and 2002

Settlement	% of hh using fuel		Trip duration (min)	
	1991	2002	1991	2002
Athol	97	94	207±11	233±16
Okkerneutboom	51	28	277±27	338±23
Rolle	68	45	239±15	259±17
Welverdiend	90	78	268±16	289±13
Xanthia	83	79	207±12	220±13
Mean	78	64	239±15	268±21
Significance	$\chi^2 = 4.8$; $p<0.05$		$Z = 3.20$; $p<0.001$	

Data show the mean and the standard error.

4.4. Species preferences

Respondents in both years showed a distinct preference for particular tree species as sources of fuelwood (Table 6). The two most popular species in both years were *Dichrostachys cinerea* and *Terminalia sericea*, although the percentage of respondents mentioning either declined markedly between 1991 and 2002. Other species mentioned by more than 20% of respondents in either year, and hence were the most commonly preferred, included *Dalbergia melanoxylon*, *Sclerocarya birrea*, *Combretum collinum*, *C. imberbe* and *C. apiculatum*. All these species, other than *S. birrea*, yield relatively dense wood, favoured for fires. Of the 27 preferred species listed across all respondents, 10 showed a decline of 5% or more from 1991 to 2002 in the proportion of respondents rating it as a preferred species (*Acacia gerrardii*, *Combretum collinum*, *C. imberbe*, *Dalbergia melanoxylon*, *Dichrostachys cinerea*, *Faurea saligna*, *Parinari curratellifolia*, *Peltophorum africanum*, *Sclerocarya birrea* and *Terminalia sericea*), whilst three exhibited an increase (*Afzelia quansensis*, *Combretum apiculatum* and *Eucela natalensis*). Although the number of species listed increased at four of the five villages from 1991 to 2002, the change was not significant (T=1.05; p>0.05). The exception was Okkerneutboom. Overall, there was an increase in the mean diversity index associated with species preferences over the 11 years (T=3.31; p<0.05). Disaggregating the picture per village indicated that respondents at all settlements added to and lost species from the list of preferred species between 1991 and 2002. This corresponds with changes in perceptions of relative abundance or scarcity of specific species (Table 7). Overall, the ease of collection of 26 species was ranked into three classes by respondents. If one assumes that those species that were ranked in 1991 but no longer so in 2002 were dropped from the list of preferred species because of increased scarcity, then the majority of the 26 species had become harder to locate in 2002 relative to 1991. Two species (*Combretum apiculatum* and *C. imberbe*) seemed easier. The mean scarcity rank across all species increased in 2002 for every village (T=2.8; p<0.05). The modal rank per village increased one class for Rolle, Welverdiend and Xanthia, remained the same at Athol and increased slightly at Okkerneutboom. There seemed to be little pattern between the 2 surveys with respect to use of traditionally taboo species. Historically certain fruit species were not allowed to be cut (e.g. *Diospyros mespiliformis*, *Sclerocarya birrea* and *Strychnos* species). The data indicate that reference to some of these as a preferred fuelwood declined between 1991 and 2002, whilst others remained constant. Several were reported to be harder to find, but the same applied to non-taboo species. There was no pattern of previously taboo species now becoming common fuelwood species over the period of this study. Where that has occurred, it did so long before the first time period of this study, i.e. prior to 1991.

Table 6
Tree species given in fuelwood collectors' list of five most preferred species for five villages in 1991 and 2002

Species	1991						2002					
	A'ol	O'boom	R'le	W'nd	X'thia	Mean	A'ol	O'boom	R'le	W'nd	X'thia	Mean
Declining												
Dichrostachys cinerea	85	68	64	89	49	71	51	39	19	40	84	47
Terminalia sericea	68	73	82	13	93	66	49	17	28	11	25	26
Dalbergia melanoxylon	62	35	32	42	8	36	47	26	11	24	4	22
Sclerocarya birrea	40	46	36	6	22	30	43	30	19	13	7	22
Combretum imberbe	40	27	28	48	0	29	19	22	14	32	7	19
Combretum collinum	15	0	14	39	78	29	3	0	3	0	9	3
Parinari curatellifolia	0	24	0	0	53	15	0	4	3	0	12	4
Faurea saligna	0	0	0	0	68	14	1	0	0	0	33	7
Peltophorum africanum	0	11	14	0	10	7	3	0	0	0	1	1
Acacia gerrardii	7	0	0	24	0	6	0	0	0	0	0	0
Increasing												
Combretum apiculatum	28	22	22	0	15	17	31	30	22	16	22	24
Afzelia quansensis	0	0	0	0	7	1	6	4	3	29	27	14
Euclea natalensis	0	0	0	11	0	2	6	0	10	27	15	12
Constant												
Diospyros mespiliformis	31	8	44	8	15	21	28	17	25	13	6	18
Combretum hereroense	26	0	6	66	0	20	26	13	6	50	3	20
Acacia burkeii	31	16	8	21	0	15	21	13	25	25	6	18
Bauhinia galpinii	0	0	6	58	0	13	0	13	0	45	0	12
Strychnos madagascariensis	18	11	24	0	8	12	17	0	22	0	0	8
Gymnosporia senegalensis	10	11	6	11	0	8	15	4	6	3	3	6
Pterocarpus angolensis	0	16	10	0	7	7	6	0	6	21	17	10
Philenoptera violacaea	0	5	8	0	0	3	3	0	11	0	0	3
Acacia ataxacantha	0	8	0	0	0	2	0	0	0	0	0	0
Acacia swazica	0	5	0	0	0	1	0	0	0	0	0	0
Pterocarpus rotundifolius	0	0	0	0	0	0	0	0	6	2	0	2
Schotia brachypetala	0	5	6	0	0	2	0	0	0	0	0	0
Strychnos spinosa	0	0	8	0	0	2	3	0	0	0	0	0.6
Trichilia emetica	0	0	0	0	0	0	1	0	0	0	3	1
Total no. of species	13	17	18	13	13		20	13	18	18	18	
Simpson's diversity index	0.44	0.62	0.56	0.44	0.39		0.77	1.78	2.26	0.90	0.91	
No. of species lost							1	7	4	2	1	3.0
No. of species gained							8	3	4	4	6	5.0

Data show percentage of collectors mentioning a species.

Table 7
Degree of difficulty of collecting preferred tree species for fuelwood around five villages in 1991 and 2002

Species name	1991					2002				
	A'ol	O'boom	R'le	W'nd	X'thia	A'ol	O'boom	R'le	W'nd	X'thia
Acacia ataxacantha		2			3					
Acacia burkeii	2	2	3	2		2	2	3	1	3
Acacia gerrardii	2	1	2	1						
Acacia swazica	2	2	1	3						1
Afzelia quanzensis			1		1	1	3	3	2	
Bauhinia galpinii			2	1			2		1	2
Combretum apiculatum	2	3	1	3	2	2	2	1	2	2
Combretum collinum	2	1	1	1	1	3				2
Combretum hereroense	2	1	2	1		2	2	3	1	3
Combretum imberbe	2	2	2	3		2	1	2	2	2
Dalbergia melanoxylon	2	2	2	2	2	1	2	2	2	2
Dichrostachys cinerea	2	2	1	2	1	1	2	2	1	1
Diospryros mespiliformis	1	2	2	1	2	1	1	2	1	2
Euclea natalensis		1	1	1		3		2	2	1
Faurea saligna					2	3				1
Philenoptera violacea	1	1	1			2		2		
Gymnosporia senegalensis	2	2	2	1		1		3	3	3
Parinari curatellifolia		1	1		1		3	2		2
Peltophorum africanum	2	1	2	1	2	2				3
Pterocarpus angolensis		2	2		2	2		3	2	2
Schotia brachypetala		2	2	1						
Sclerocarya birrea	1	1	1	1	1	2	2	2	2	2
Strychnos madagascariensis	1	2	2		2	3	2	2		
Strychnos spinosa		1	1		1	2				
Terminalia sericea	1	1	1	3	1	2	2	2	2	1
Trichilia emetica		1	1		1					3
Modal score	2	1/2	1	1	1	2	2	2	2	2
Mean score	1.8	1.6	1.5	1.6	1.6	1.9	2.0	2.3	1.7	2.0

Data show median difficulty where 1 = easy; 2 = moderate; 3 = very difficult.

4.5. Frequency of woodcutting

In Bushbuckridge, fuelwood gatherers frequently cut live wood because of the relative scarcity of deadwood. The proportion of households admitting to cutting wood in the region was 53% and 49% in 1991 and 2002, respectively (Table 8). Many respondents were reluctant to admit their involvement in wood cutting, except where this was obvious, such as a pile of recently cut wood within the vicinity. Such reluctance was related to fears of arrest. It is therefore likely that the figures were understated. Over 60% of respondents in 2002 reported that wood collection was more difficult at the time of the survey than it had been in the recent past (5 years earlier). Interestingly, respondents in 1991 gave a similar response, suggesting that wood collection has been difficult in the area for a long time.

Table 8
Incidence of and reasons for cutting trees reported by fuelwood collectors from villages in 1991 and 2002

	Year	Settlement					Mean	Significance
		Athol	O'boom	Rolle	Welv'd	Xanthia		
% hh cutting	1991	30	34	55	76	72	53	$\chi^2 = 0.32$
	2002	55	61	50	40	40	49	$p > 0.05$
Cutting used to be allowed so we continue doing it	1991	11	24	18	15	10	17	$\chi^2 = 0$
	2002	4	17	21	33	11	17	$p > 0.05$
Dry wood is not as plentiful as it used to be	1991	58	48	53	29	63	50	$\chi^2 = 0.72$
	2002	60	35	87	49	42	56	$p > 0.05$
There are more people now so dry wood is hard to find	1991	25	30	21	50	27	31	$\chi^2 = 3.2$
	2002	30	7	16	13	32	20	$p > 0.05$
It is dangerous to walk far because in criminals might attack one	1991	0	0	0	0	0	0	$\chi^2 = 6.2$
	2002	0	17	5	3	3	6	$p < 0.05$
Respondent is too old and cannot walk far to collect dry wood	1991	0	0	0	0	0	0	$\chi^2 = 5.3$
	2002	3	0	6	5	13	5	$p < 0.05$

Data are percentage of tree cutters.

The most common reason stated for cutting live wood was that there was insufficient dead wood available in the surrounding communal lands (Table 8). The common reason advanced in both years for the increased difficulty of wood collection was that dry wood was not easily available. This can be linked to those who stated that it was because of increasing numbers of people, houses and fields, which made it harder to locate dry wood. Two new reasons were provided in 2002, one relating to the presence of criminals deterring respondents from walking long distances to locate dry wood, and the other that they were getting old and could not longer walk far. The latter suggests an aging population, or that younger households are more reliant on electricity.

5. Discussion and conclusions

The results of the new South African government's post-apartheid era large-scale national electrification programme were evident in the study area. During the 1991 survey, only three households had access to electricity in all the sample settlements, while in 2002 almost all the households in Okkerneutboom, Rolle, Welverdiend and Xanthia had been connected to the national grid. Only the settlement of Athol had no access to grid electricity. At the time of the 1991 survey, connection fees ranged from R900 to R1 091 at the 1991 value of the South African Rand (Griffin et al., 1992). However, with the new policies in place, households reported paying connection fees ranging from R62 to R123 in 1997/8 onwards (R33–R67 in 1991 equivalents) and as a result almost 100% of households were electrified in four of the five settlements.

In both surveys, fuelwood, whether purchased or collected, was the most widely used fuel in all the sample settlements (Madubansi, 2003). About 97% and 94% of households collected fuelwood in 1991 and 2002 respectively, while the percentage of households purchasing fuelwood rose from 27% in 1991 to 31% in 2002. Many households both collected and purchased wood. The slight increase in the percentage of households purchasing fuelwood (a 4% absolute increase, but a 15% relative increase) possibly indicates that there was an increase in fuelwood scarcity in the local environment around the settlements, as purchasing is a common strategy employed in the face of declining local fuelwood stocks (Vermeulen et al., 2000; Brouwer and Falcão, 2004). This possibility was also supported by the increased time recorded for fuelwood collection trips. The average duration of fuelwood collection trips increased significantly from 239 in 1991 to 268 min in 2002, a 12% increase. Aerial photographic analysis of the region as a whole (Pollard et al., 1998) and a few individual settlements within the region have shown a marked decrease in fuelwood resources (Giannecchini, 2001), most markedly for large settlements. A large proportion of fuelwood users in those two settlements purchased most of their fuelwood or supplemented collected fuelwood with bought fuelwood. By 2002 purchased fuelwood in these two settlements was more expensive than in either Welverdiend or Xanthia, and on a par with Athol.

Despite the increase in fuelwood scarcity and the availability of electricity, the majority of households continued using wood as their main source of energy for thermal applications. This emphasises the importance of fuelwood as an energy source for cooking, heating water and keeping warm. Yet the proportion of households lighting a fire (outside) for keeping warm had decreased dramatically. We hypothesise that this may be a consequence of the introduction of electrical lighting and hence people spend the evenings indoors. Gandar (1994) referred to fuelwood as a staple energy source for most rural households. He further stated that the primacy of fuelwood in the rural economy of South Africa would continue in the medium term at least, even if a vigorous programme of rural electrification was implemented and access to transitional fuels were improved. This seems to be the case for the majority of the households in this study, as found elsewhere in Africa; for example Kenya (Kituyi et al., 2001), Mozambique (Brouwer and Falcão, 2004) and Zimbabwe (Hosier and Dowd, 1987; Vermeulen et al., 2000).

In terms of cooking energy, fuelwood retained its traditional importance in all the sample settlements being used by more than 90% of the households. There were no quantitative trends indicating a shift from fuelwood to other fuels, particularly electricity after 11 years. This parallels finding of Davis (1998), Vermeulen et al. (2000) and Brouwer and Falcão (2004) who also showed relatively little change in the predominance of fuelwood as the main cooking fuel even when electricity was available.

The monthly consumption rates of fuelwood remained unchanged between 1991 and 2002. Annual consumption was approximately 3.8 tons per household, which is well within the range reported by others from the southern African region (Shackleton, 1993). Only 1% of the households in the region used only electricity for all thermal purposes. A few households that used paraffin and gas for cooking did so in combination with fuelwood. Thus, rural households have a complex mix of energy sources that they use at different times and for different purposes (Vermeulen et al., 2000; Madubansi, 2003), as do poor peri-urban and urban communities (Soussan et al., 1990; Davis, 1998; Brouwer and Falcão, 2004). Only in more affluent communities (rural and urban) do households tend to adopt a greater reliance on electricity alone (Davis, 1998; Mahari and Howorth, 2001; Brouwer and Falcão, 2004). The continued use of wood could be attributed to the fact that it was obtained free and was believed to cook food faster than the other fuels. In cases where it was purchased, it was relatively cheaper than the other fuels. The mean annual increment in the price of fuelwood over the past 11 years was only 4.2%, which was a lot less than the other commercial fuels (paraffin, gas, batteries), and less than the inflation rate. Additionally, the use of fuelwood for cooking and heating does not require the use of expensive appliances. The observed trends are in agreement with White et al. (1997) who observed that the majority of poor people who have access to electricity avoid using it for those needs that have a high-energy demand and for which the appliances are specialised and relatively expensive, such as cooking and space heating. Similar results were obtained in Zimbabwe and Kenya where rural inhabitants preferred using wood for thermal applications because it was a free commodity and in cases where it was purchased it was relatively cheaper than other fuels (Marufa et al., 1996; Kituyi et al., 2001).

Fuelwood collectors in both surveys generally showed a distinct preference for particular species, in common with work elsewhere (Tietema et al., 1991; Shackleton, 1993; Tabuti et al., 2003), although Grundy et al. (1993) reported no selectivity for fuelwood species at their study site in Zimbabwe. Respondents in Athol, Okkerneutboom and Rolle preferred *D. cinerea*, *T. sericea* and *D. melanoxylon*, while respondents in Welverdiend and Xanthia preferred *Combretum* species, all of which have relatively dense wood that burns well with little smoke, which are important attributes of preferred species (Tabuti et al., 2003). The two most widely preferred species across all sites in both years were *D. cinerea* and *T. sericea*, although the proportions of households using them declined markedly between 1991 and 2002. Indeed, use of 10 of the 27 preferred species listed (37%) had declined by 5% or more across households, whereas an increase in the proportions of households using any of the preferred species was recorded for only three species (11%).

Not only had the use of individual species changed between the two surveys, so too had the total number of species used. More species were mentioned in 2002 than in 1991 for each settlement. Overall, there was a significant increase in the diversity of species collected in 2002 relative to 1991, indicating increased number of species and lower dominance of any single species. The increase in the number of species burnt could possibly be ascribed to an increasing fuelwood scarcity in the area. In the face of increasing scarcity of preferred species, collectors resort to less popular species thus widening the range of collected species (Shackleton and Prins, 1992). In this study, the majority of the 26 preferred species had become harder to locate in 2002 relative to 1991, and only two (*Combretum apiculatum* and *C. imberbe*) were seemingly easier to locate, although this might be a spurious interpretation. Both these species have relatively hard wood, the latter being renowned in South Africa for its extremely dense wood. It might be that in 1991 and earlier they were not readily collected because of the time required to cut them because they are so hard. But as scarcity of wood in general has increased, local harvesters might now have to use these woods. The mean scarcity rank averaged across all species increased in 2002 for every village. The modal rank per village increased one class for Rolle, Welverdiend and Xanthia, remained the same at Athol and increased slightly at Okkerneutboom. It can be expected therefore, that as fuelwood becomes scarcer in the region, there will be a further shift to less preferred species and increased adoption of alternative fuel types. This was very evident at Okkerneutboom and Rolle where fuelwood collectors reported scavenging for any piece of wood irrespective of its burning properties. As was noted in the 1991 survey, ease of collection was not the only determining factor for the popularity of species as *A. burkeii* and *C. apiculatum* remained popular fuelwood species in spite of their being fairly difficulty to collect.

Given the universal preference for dead wood over live wood, fuelwood scarcity in the area was further evidenced by the high proportion of respondents (approximately 50%) that admitted cutting live wood as opposed to collecting only dead wood. There are local rules against harvesting of live wood without a permit, but these are rarely enforced. Yet, because of these rules, a number of respondents were reluctant to admit to cutting live wood. Consequently, the results here are likely to be an underestimate of the proportion of people cutting live wood, as has been commented upon by other authors (Eberhard, 1986; Griffin et al., 1992). The reasons for cutting live wood were relatively similar between the two surveys except for the large decline in the proportion of households saying they did so because they had been allowed to do so in the past.

In conclusion, this longitudinal study using the same survey instrument has revealed a number of attributes of rural demand for fuelwood that need to be considered by energy and conservation planners. Firstly, the introduction of electricity into the region has, as yet, had little impact on the prevalence of use and consumption rates of fuelwood, despite increasing time and effort required to locate adequate local stocks, and 6 kWh provided free per household per month. Secondly, local decline in the availability of fuelwood has promoted the adoption of a number of strategies by local communities, corroborating previous work. These strategies include (i) walking further to collect fuelwood as measured through the time taken per collection trip, (ii) increased purchase of fuelwood which is harvested further afield and transported into the region, (iii) a change in preferred species, and (iv) inclusion of a greater diversity of fuelwood species collected. The most commonly identified solution by the survey respondents to increasing scarcity and the increasing hardship was that the government should decrease the price of electricity so that people could use it for cooking purposes. Lastly, the results show that the localised patterns of use and changes over time are extremely dynamic between the five villages. This corresponds with a model of dynamic rural livelihoods that are in a constant state of flux in response to local and macro conditions, where people seek to optimise the opportunities available at any single time (Vermeulen et al., 2000). This poses considerable challenges to external interventions in both the conservation and energy sector. The increasing direct and opportunity costs of securing fuelwood supplies need to be considered against the costs of alternatives and the social dynamics of who controls household expenditure (Madubansi and Shackleton, In press).

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