Household Firewood Utilization around the Hlatikhulu Forest Reserve, South Africa

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Research

Abstract

A study to define firewood use and sustainability was commissioned by South Africa's KwaZulu-Natal nature conservation authorities. The intention is to define current firewood use around a small Afromontane forest reserve situated in the Maputaland - Pondoland - Albany biodiversity hotspot in order to plan the delivery of alternatives sources of energy and preserve the forest. A total of 121 rural households were surveyed to define current patterns of firewood use. The results showed that households used an average of 134 firewood bundles per year, representing an annual firewood volume of 25.4 m^3 per household. A firewood bundle lasted for six days in summer and two days in winter. This study further showed that 29 woody species were actually used, 41 species were reported as being used, and six species constituted the bulk of utilization (70.8% of volume). Among these, *Diospyros dichrophylla* (Gand.) De Winter (7.90% of volume used) is an abundant shrub occurring on degraded forest sections or fallow fields, with potential as an alternative firewood resource. The study results highlight the reliance on firewood with more than 90% of households using firewood for cooking and heating.

Introduction

Firewood use as an energy source in rural Africa remains a key issue as the majority of people cannot afford other energy forms for cooking and heating (Boudreau *et al*. 2005, Shackleton *et al*. 2007). While firewood is a renewable resource, population growth, development activities, and over-utilization provide a challenge to the sustainability of firewood resources (Gaugris & Van Rooyen 2010, Shackleton 1998). Previous research raised two key questions (Gaugris & Van Rooyen 2007, Gaugris *et al*. 2007, Obiri *et al*. 2002): (1) Until an alternative exists, what is sustainable utilization? and (2) Which ecological threshold requires supply of alternatives?

These questions need answers in order to implement development actions providing people alternative energy source solutions without unforeseen negative impacts before ecologically threatening thresholds are reached (Kyle 2004, Madubansi & Shackleton 2006).

Rural communities in the KwaZulu-Natal, South Africa, face such problems, and the local government seeks information to deliver timely suitable solutions while accommodating budgetary constraints and timelines. The KwaZulu-Natal's conservation authorities commissioned a study to investigate ecological and social sustainability of resource harvesting from Hlatikhulu Forest Reserve (HFR) in Maputaland. This study, among a range of objectives, investigated households' firewood use to define current use in terms of volume of wood and the composition of species preferred by people. Preliminary firewood

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use patterns are presented here and local preferences for species and sizes are evaluated.

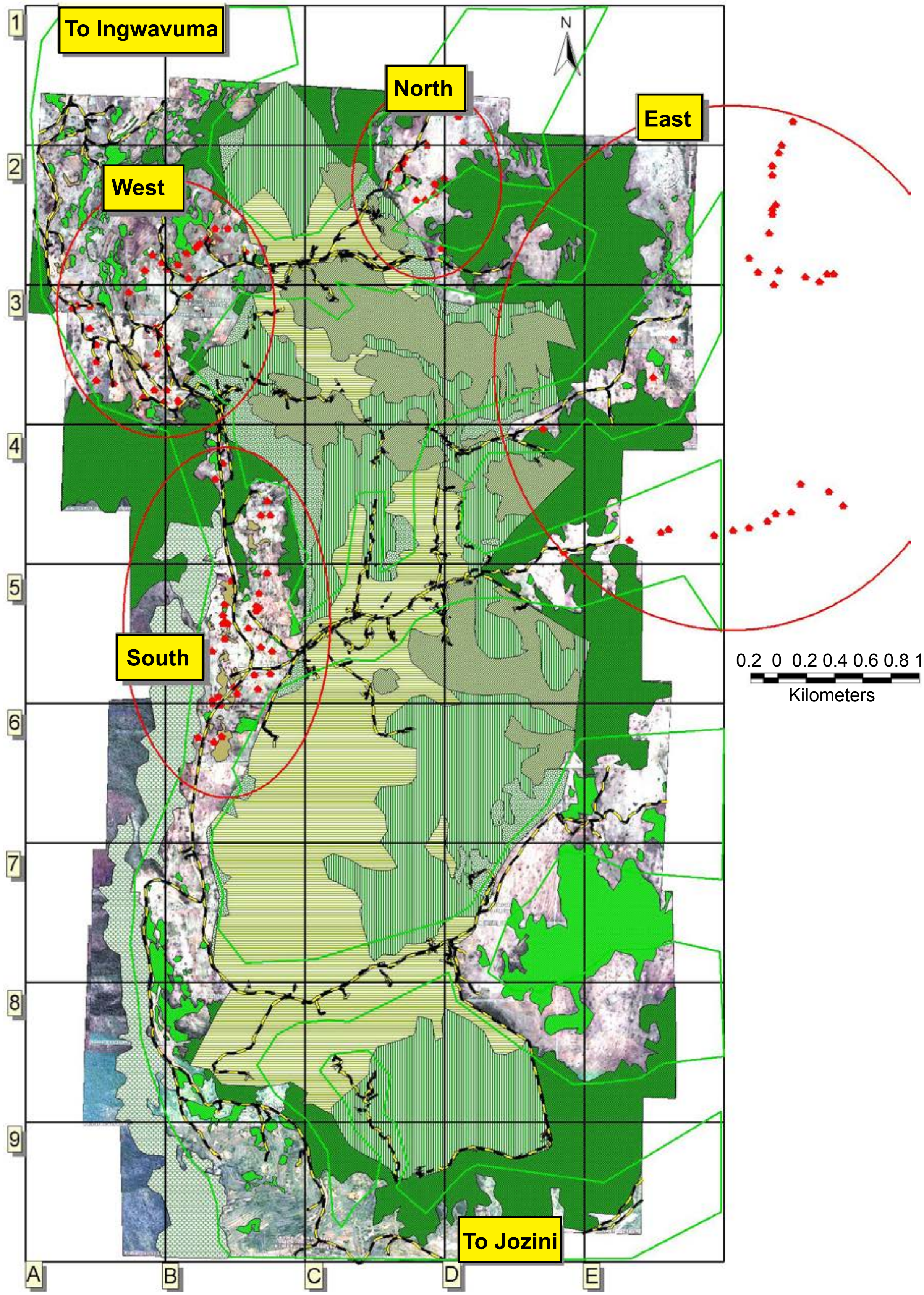
Study Area

The study area lies in South Africa, within the Maputaland - Pondoland - Albany biodiversity hotspot. A rectangular area of 9 km from south to north and 5 km from west to east (4500 ha) was considered, within which HFR's 1600 ha lie (Figure 1). HFR straddles the crest and eastern shoulder of the Lebombo Mountain range between altitudes of 600 to 800 m. Mean rainfall is 920 mm per year, while mean temperature ranges from 18.4°C in winter to 21.5°C in summer. The HFR protects an Afromontane forest remnant composed of three forest vegetation types (Mucina & Rutherford 2006). A main road dotted with settlements links the towns of Jozini and Ingwavuma along the crest and borders the east of the reserve from south to north. Human pressure on the reserve is intense.

Methods

The use of energy (firewood and/or other) for cooking and heating was evaluated during a census of the 121 households that represent the study area. In line with census procedures, all households were visited. This census was conducted in September 2007. When a firewood bundle was present at the time of the census, species within the bundle were identified by the researcher and his assistant, with the help of the respondent when uncertainty arose. In such instances of uncertainty on the identification, the respondent was requested to describe the plant and to show a similar plant in the vicinity if possible. Each firewood element in the bundle was measured (total length and middle diameter). If another source was used, this was documented. Irrespective of whether a firewood bundle was present, people were also asked to list and describe, as well as rank, the five species that they utilized the most. In both cases, people were asked to estimate the number of days that a bundle of the type that they collected would last in summer or in winter (providing all energy requirements for each of these two periods). This dis-

Figure 1. The study area (above in green block and on opposite page) around the Afromontane forest reserve, Maputaland - Pondoland - Albany biodiversity hotspot, KwaZulu-Natal, South Africa. Each grid block has an area of 1 km^2. Yellow shading indicates high human influence. Red house symbols indicate surveyed households. Reserve limits are shown in thick red (this page) and black (opposite page) lines. The stippled ellipses represent the four sectors where people have settled that were considered for the study.


To Ingwavuma
N
North
East
West
South
0.2 0 0.2 0.4 0.6 0.8 1
Kilometers
To Jozini
1
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tinction between winter and summer was important due to the clear changes in weather (rainfall and temperature) between the two seasons. Moreover the study area, due to its geographic situation on the first mountain range inland from the coast line, is directly exposed to weather with rapid changes in conditions.

Results provided in this study represent both the quantitative sample of the firewood bundles obtained during the census and the qualitative list of species as preferred by the people. The quantitative aspects are analyzed in more depth rather than the qualitative overview provided by the people (when bundles were not available for sampling), as they were considered more reliable for the purposes of defining metrics.

From the qualitative list provided by people, a weighted species preference list was constructed. The questionnaires requested that people list species used for firewood by order of preference. Depending on their rank, species were given a weight as follows:

Rank	Description	Weight
1st	Most preferred	5
2nd	Second most preferred	4
3rd	Average	3
4th	Lower desirability	2
5th	Low desirability	1
6th	Replacements/Least desirable	0.5

The rank weight was multiplied by the number of times a species was classified in each of the ranks, and a final weighted species list was provided. A Kruskal-Wallis test was performed on the rank scores first for all species and then only for the 6 most selected species to evaluate whether a significant difference occurred in ranking values.

From the total number of firewood bundles sampled in the study area during the census of 121 households, the following aspects were calculated:

- mean number of firewood elements used;
- mean diameter and length of firewood elements;
- mean volume of firewood used, calculated as the product of "mean number of firewood elements used" by "mean volume of a single firewood element"; mean volume was calculated using the mean diameter and length dimensions;
- mean number of species found in a firewood bundle;

The number of days needed to consume a firewood bundle was determined for winter and summer seasons, and values given were compared through a Mann-Whitney U test.

In order to evaluate whether households selected a specific diameter or length, single factor ANOVAs were run to compare the diameters and lengths of woody elements selected. ANOVAs were selected as the number of samples provided sufficient guarantee for the use of parametric statistics (Motulsky 2005).

The households in the study area were geographically positioned in four broadly separate clusters that enabled them to access the forest reserve through different entry points. The households could therefore be regrouped in a similar fashion to see whether differences could be perceived between the clusters in their approach to firewood use. The clusters constituted are labelled by their broad geographic situation in relation to the HFR (North, South, East, West). Single factor ANOVAs were performed to define whether differences occur between the four household clusters in terms of (1) the number of firewood elements in a bundle, (2) the number of woody species in a bundle, and (3) the mean volume of a firewood bundle.

Results

Firewood use is mostly for cooking meals (usually one meal per day) and heating at least one common room (usually the kitchen) where people eat. In households where alternative cooking energies were found (such as gas stoves and paraffin stoves), fires remained used for heating in winter or during bad weather spells. From 121 households sampled, 92% used firewood as a main energy source for cooking and heating (Table 1). Households

Table 1. Household energy use for cooking and heating in the Hlathikulu Forest Reserve region of South Africa. n = number of households using the described energy type.

Energy type	n	%
Households using firewood	110	91
Households not using firewood	10	8
Households using other energy	15	12
Households using gas stoves	9	7
Households using electric stoves / generators	2	2
Households using energy efficient wood stoves	3	3
Households using paraffin stoves	3	3
Total households sampled	121	

Table 2. Mean firewood bundle characteristics from sampled households in the Hlatikhulu Forest Reserve region of South Africa. P-values reported are either from an ANOVA comparing means among four village clusters (North, South, East, West; Characters 1–5) or from a Mann-Whitney U test (comparing bundle longevity in Summer versus Winter). SD = standard deviation. ‡ = number of bundles sampled. ^ = number of elements within 36 bundle sampled. † = number of households sampled.

Character	Mean	SD	n	Max	Min	P-value
1. Number of woody elements per bundle	22.1	7.2	36‡	41	10	< 0.01
2. Volume (m^3) of woody elements per bundle	0.19	0.2	36‡	1	0.01	0.60
3. Number of species per bundle	3.92	1.0	36‡	6	1	< 0.01
4. Length (m) of woody elements selected	1.68	0.7	795^	4.5	0.5	0.30
5. Diameter (cm) of woody elements selected	7.53	5.2	795^	22	1	0.26
6. Bundle longevity (days) - Summer	6.25	0.7	110†	30	3	< 0.001
7. Bundle longevity (days) - Winter	1.96	0.7	110†	14	1	

also used gas stoves (8% of households), paraffin stoves (3% of households), and electric stoves (powered from a generator – 2%). Only 3% of households had energy efficient wood burning stoves. Electricity from photovoltaic solar panels was not sufficient to power cooking devices.

An average standard firewood bundle contains 22 firewood elements (Table 2), each measuring on average 1.68 m long and 7.53 cm in diameter (Table 2). The mean volume per firewood bundle was 0.19 m^3 (Table 2). The bundles were species poor, and only one to six species were ever identified in a single bundle, with a mean of four species (Table 2). No specific selection was apparent for either diameter (F = 1.20, P = 0.26, df = 96) or length (F = 1.16, P = 0.30, df = 97) of the firewood pieces.

A significant difference appeared between the four village clusters in terms of number of elements found in a bundle (F = 4.59, P <0.01, df = 35). Villages to the east, north, and west of the study area used significantly more elements than the villages in the south. The number of species found in a bundle also differed between villages (F = 6.03, P <0.01, df = 36) with east, north, and west villages having significantly more species in their selection than villages located in the south. The reason behind the significant difference in the southern sector is unknown and cannot be explained with the available data. However, these differences in species and number results did not translate into a significant difference in terms of firewood bundle volume (F = 0.62, P = 0.60, df = 35), which could be considered as similar across the study area.

An average firewood bundle was estimated to last six days in summer and two days in winter or bad weather conditions (Table 2). Winter conditions were deemed to prevail from May to November inclusive (214 days, based on months where mean month temperature was below mean annual temperature), while summer conditions prevailed from December to April (151 days). A household needs an average of 134 firewood bundles, representing an annual volume of 25.4 m^3 of firewood. The “lasting” potential of a firewood bundle was significantly different between winter and summer (U = 120.5, P <0.001), thereby justifying the use of two different measures.

A total of 29 species were identified in the firewood bundles sampled and are listed in Table 3. The three most utilized species in terms of volume were: *Drypetes arguta* (Müll.Arg) Hutch. (confusion with *Drypetes gerrardii* Hutch. could be possible), *Strychnos henningsii* Gilg, and

Table 3. Species composition of firewood bundles from the households of the Hlatikhulu Forest Reserve region of South Africa. Rankings reflect individual volumes relative to the total volume of all sampled bundles (N = 36).

Rank	Species	Volume in m^3	%
1	*Drypetes arguta* (Müll.Arg) Hutch.	2.04	20.61
2	*Strychnos henningsii* Gilg	1.58	16.03
3	*Heywoodia lucens* Sim	1.00	10.08
4	*Celtis africana* Burm.f.	0.89	8.98
5	*Diospyros dichrophylla* (Gand.) De Winter	0.78	7.90
6	*Strychnos decussata* (Pappe) Gilg	0.71	7.20
7	*Eugenia capensis* subsp. *natalitia* (Sond.) F.White	0.64	6.48
8	*Ptaeroxylon obliquum* (Thunb.) Radlk.	0.52	5.24

Rank	Species	Volume in m³	%
9	*Ochna arborea* Burch. ex DC.	0.34	3.48
10	*Premna mooiensis* (H.Pearson) W.Piep.	0.29	2.93
11	*Combretum kraussii* Hochst.	0.22	2.20
12	*Combretum collinum* Fresen.	0.19	1.90
13	*Acalypha glabrata* Thunb.	0.15	1.54
14	*Acacia ataxacantha* DC.	0.12	1.17
15	*Celtis gomphophylla* Baker	0.11	1.10
16	*Kraussia floribunda* Harv.	0.07	0.67
17	*Trema orientalis* (L.) Blume	0.06	0.64
18	*Brachylaena elliptica* (Thunb.) Less.	0.05	0.46
19	*Justicia adhatodoides* (Nees) V.A.W.Graham	0.04	0.36
20	*Grewia occidentalis* L.	0.02	0.25
21	*Eucalyptus* spp.	0.02	0.19
22	*Dombeya burgessiae* Gerrard ex Harv.	0.01	0.12
23	*Dichrostachys cinerea* (L.) Wight & Arn.	0.01	0.10
24	*Buxus natalensis* (Oliv.) Hutch.	0.01	0.09
25	*Brachylaena discolor* DC.	0.01	0.08
26	*Ziziphus mucronata* Willd.	0.01	0.08
27	*Cryptocarya woodii* Engl.	0.01	0.05
28	*Chrysophyllum viridifolium* J.M.Woods & Franks	0.00	0.03
29	Unidentified species	0.00	0.03
30	*Canthium inerme* (L.f.) Kuntze	0.00	0.02

Heywoodia lucens Sim. These three species represent 46.7% of the total volume of firewood used.

In terms of species preference indicated by people, the diversity of species currently used for firewood is higher with a total of 41 species listed and ranked by people based on the questionnaires undertaken (Table 4). The species ranked highest in freelists was *Diospyros dichrophylla* (Gand.) De Winter, though it ranked 5th in terms of volume (7.90%). All species found within the sampled bundles were also listed, and their volume-based ranks are listed for comparison purposes. A significant difference (KW = 94.93, $P < 0.001$, no. of groups = 41) occurs in the rankings listed overall, indicating that some species are more interesting or more favored than others. However, no significant difference appears between the 6 most preferred species based on rankings provided by local people (KW = 0.93, P = 0.96, no. of groups = 6), indicating that all 6 may be equally acceptable and interchangeable.

Table 4. Ranking of species listed as preferred (RL) by local people in the Hlatikhulu Forest Reserve region of South Africa. Rankings from detailed bundle examinations (RB) are included for comparison and overall weighted ranks have been generated. WTS = weighted total for species.

RL	RB	Scientific name	Weighted totals for each rank							WTS
			1	2	3	4	5	6	7	
1	5	*Diospyros dichrophylla* (Gand.) De Winter	130	56	15	8	4	-	-	213.0
2	1	*Drypetes arguta* (Müll.Arg) Hutch.	130	40	27	10	6	-	-	213.0
3	13	*Acalypha glabrata* Thunb.	35	48	30	28	5	-	0.5	146.5
4	2	*Strychnos henningsii* Gilg	35	48	36	16	4	-	-	139.0
5	8	*Ptaeroxylon obliquum* (Thunb.) Radlk.	20	36	24	8	4	-	-	92.0
6	24	*Buxus natalensis* (Oliv.) Hutch.	20	28	27	6	3	1	-	85.0

RL	RB	Scientific name	Weighted totals for each rank							WTS
			1	2	3	4	5	6	7	
7	6	*Strychnos decussata* (Pappe) Gilg	20	24	15	18	4	-	-	81.0
8	9	*Ochna arborea* Burch. ex DC.	30	12	18	8	-	-	-	68.0
9	4	*Celtis africana* Burm.f.	-	20	9	14	3	0.5	-	46.5
10	14	*Acacia ataxacantha* DC.	25	12	3	2	1	-	-	43.0
11	19	*Justicia adhatodoides* (Nees) V.A.W.Graham	10	12	6	10	2	-	-	40.0
12	3	*Heywoodia lucens* Sim	15	12	6	4	1	-	-	38.0
13	12	*Combretum collinum* Fresen.	15	-	9	8	2	-	0.5	34.5
14	20	*Grewia occidentalis* L.	-	8	9	10	3	0.5	-	30.5
15	16	*Kraussia floribunda* Harv.	-	8	21	-	1	-	-	30.0
16		*Volkameria glabra* (E.Mey.) Mabb. & Y.W.Yuan	10	4	6	2	1	0.5	-	23.5
17	10	*Premna mooiensis* (H.Pearson) W.Piep.	-	12	3	6	1	0.5	-	22.5
18	26	*Ziziphus mucronata* Willd.	5	4	3	-	1	-	-	13.0
19	23	*Dichrostachys cinerea* (L.) Wight & Arn.	-	12	-	-	-	-	-	12.0
20	30	*Canthium inerme* (L.f.) Kuntze	-	8	-	2	1	-	-	11.0
21	11	*Combretum kraussii* Hochst.	5	-	3	2	1	-	-	11.0
22		*Searsia chirindensis* (Baker f.) Moffett	-	4	6	-	1	-	-	11.0
23		*Cassipourea malosana* (Baker) Alston	10	-	-	-	-	-	-	10.0
24	27	*Cryptocarya woodii* Engl.	-	-	9	-	1	-	-	10.0
25	21	*Eucalyptus* spp.	-	8	-	2	-	-	-	10.0
26		*Vepris lanceolata* G.Don	10	-	-	-	-	-	-	10.0
27	15	*Celtis gomphophylla* Baker	-	-	9	-	-	-	-	9.0
28	25	*Brachylaena discolor* DC.	-	-	3	2	1	-	-	6.0
29		*Drypetes gerrardii* Hutch.	5	-	-	-	-	-	-	5.0
30	7	*Eugenia capensis* subsp. *natalitia* (Sond.) F.White	5	-	-	-	-	-	-	5.0
31	17	*Trema orientalis* (L.) Blume	5	-	-	-	-	-	-	5.0
32		*Casearia gladiiformis* Mast.	-	-	-	4	-	-	-	4.0
33	28	*Chrysophyllum viridifolium* J.M.Woods & Franks	-	4	-	-	-	-	-	4.0
34	22	*Dombeya burgessiae* Gerrard ex Harv.	-	-	3	-	1	-	-	4.0
35		*Lippia javanica* (Burm.f.) Spreng.	-	4	-	-	-	-	-	4.0
36		*Vangueria apiculata* K.Schum.	-	4	-	-	-	-	-	4.0
37		*Gardenia volkensii* K.Schum.	-	-	3	-	-	-	-	3.0
38		*Hyperacanthus amoenus* (Sims) Bridson	-	-	3	-	-	-	-	3.0
39		*Mimusops obovata* Sond.	-	-	3	-	-	-	-	3.0
40		*Toddaliopsis bremekampii* I.Verd.	-	-	3	-	-	-	-	3.0
41	18	*Brachylaena elliptica* (Thunb.) Less.	-	-	-	2	-	-	-	2.0

Discussion

Our findings of patterns of firewood use mainly for cooking and heating, despite the availability of alternative energy methods, are in line with findings from Madubansi and Shackleton (2006) in the Bushbuckridge area further north along the Lebombo Mountain range in South Africa. Indeed these authors stated that despite increased availability and use of electricity in households, this remained allocated towards powering "luxury" items (TV, phones, etc.) while fuel wood use for cooking remained constant in terms of weight and in percentage of households reporting use (90%) between 1991 and 2002. Considering that our study concerned an area even more remote than that of Madubansi and Shackleton (2006) where at the time of study (2007) no electricity was available, the percentage of households using firewood was surprisingly comparable.

Although the numbers of species and total elements comprising a firewood bundle did vary across villages, there were no apparent village-based patterns related to length and diameter of those elements or to total bundle volume. This indicates that while species preference may vary or local people simply use what is available to them as it comes, they still manage to produce a uniform wood bundle that represents a stable volume unit that can be used representatively for the study area.

The number of firewood species used is comparable to that indicated in the study of Madubansi and Shackleton (2007) for the Bushbuckridge area. Some widely spread species in South Africa are found in both the present study and that of these authors. Presence of *Diospyros dichrophylla* as firewood is particularly interesting. It is an abundant shrub occurring on degraded forest sections or fallow fields, and through sheer abundance, it could represent an alternative firewood resource. The biology of this locally common species merits further investigation as it is reported as a good firewood species and a good hedge species in various works (Nichols 2005). Although slow to grow, its sheer abundance in the landscape is known (the species is considered as most commonly occurring in the Lebombo Mountain range of South Africa) and indicates that it is highly suited to the area and could be used easily (Nichols 2005). Such a species could be considered for development within an agro-forestry system, in conjunction with edible fruit-bearing species.

In the short term, it appears difficult to replace firewood. However, wiser firewood use should be investigated through a combination of promoting the use of locally abundant species as well as growing such species as economically viable resources. This could be further assisted by energy efficient wood stove dissemination. The local landscape holds vast tracts of land that were previously terraced and prepared for agriculture (Figure 2). However, this land has been left fallow after the abandonment of the region by its people subsequent to the 1994 change of government in South Africa. This land is currently naturally re-vegetated by woodland and forest pioneer species and should be considered as an opportunity to test agro-forestry principles in order to promote the development of a Non-Timber Forest Products (NTFP) industry

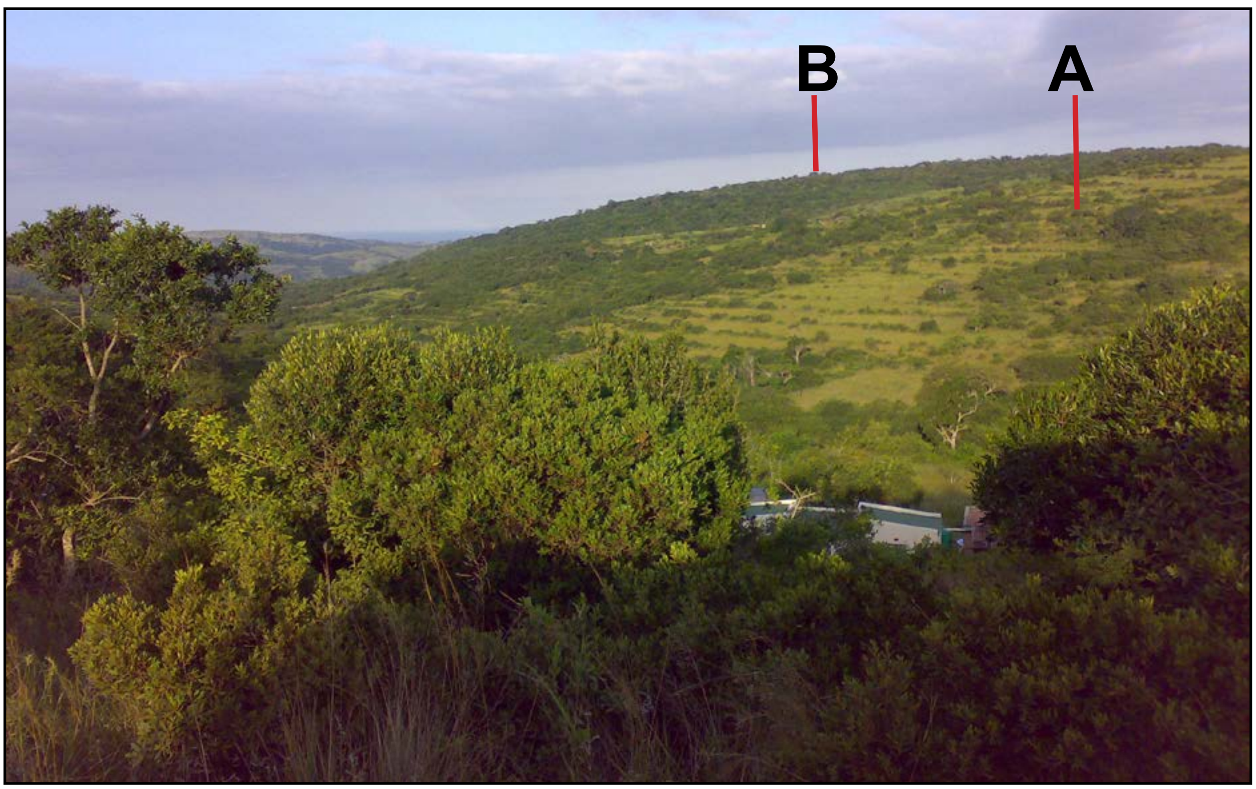

Figure 2. View over previously terraced and farmed land (**A**) in the study area around the Afromontane forest reserve (**B**), Maputaland - Pondoland - Albany biodiversity hotspot, KwaZulu-Natal, South Africa. This view highlights former fields now abandoned and fallow between successive terraces. Natural re-vegetation processes and natural accumulation of deeper soil and moisture have led to the growth of locally abundant shrubs along the former terrace ridges.

based not only on the forest reserve resources but also on the resources found on the fallow sections of land. Indeed several authors have indicated that although wealth classes occur in rural South Africa, there is an important level of reliance on NTFP from all classes, and lower income classes can find in such a practice a relatively interesting way of complementing their revenues (Shackleton & Shackleton 2006, Gaugris & Vasicek 2008). The dissemination of efficient wood stoves should further be organized as a development project by the local conservation authorities in order to assist their plans to conserve the Afromontane forest remnant. This will be required as the rural households do not have sufficient purchasing power to afford what could be considered as non-essential items (Gaugris & Vasicek 2008). In the medium to long term, the introduction of electricity as a cooking energy considered by the South African government can be investigated; however, failings ascribed to the provision of free electricity described by Madubansi and Schackleton (2006, 2007) indicate that electricity should be provided in a quantity that provides sufficient energy for cooking meals in addition to powering "luxury items," which may prove unviable from an economic point of view.

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Literature Cited

Boudreau, S., M.J. Lawes, S.E. Piper & L.J. Phadima. 2005. Subsistence harvesting of pole-size understorey species from Ongoye Forest Reserve, South Africa: Species preference, harvest intensity, and social correlates. *Forest Ecology and Management* 216(1–3):149–165. dx.doi.org/10.1016/j.foreco.2005.05.029

Gaugris, J.Y. & M.W. Van Rooyen. 2007. The structure and harvesting potential of the sand forest in Tshanini Game Reserve, South Africa. *South African Journal of Botany* 73(4):611–622. dx.doi.org/10.1016/j.sajb.2007.06.004

Gaugris, J.Y. & M.W. Van Rooyen. 2010. Woody vegetation structure in conserved versus communal land in a biodiversity hotspot: A case study in Maputaland, South Africa. *South African Journal of Botany* 76(2):289–298. dx.doi.org/10.1016/j.sajb.2009.11.007

Gaugris, J.Y., M.W. van Rooyen, J.-du-P. Bothma & M.J. Van der Linde. 2007. Hard wood utilization in buildings of rural households of the Manqakulane community, Maputaland, South Africa. *Ethnobotany Research and Applications* 5:97–114. http://hdl.handle.net/10125/224

Gaugris, J.Y. & C.A. Vasicek. 2008. *An Investigation into the Ecological and Social Sustainability of Resource Harvesting from the Hlathikulu Forest Reserve*. Unpublished report commissioned by Ezemvelo KwaZulu-Natal Wildlife, Ekotrust CC., and FLORA FAUNA & MAN, Ecological Services Ltd., Pretoria, South Africa.

Kyle, R. 2004. Resource use in the indigenous forests of Maputaland: Are conservation strategies working? Pp. 713–736 in *Indigenous Forests and Woodlands in South Africa: Policy, people and practice*. Edited by M.J. Lawes, H.A.C. Eeeley, C.M. Shackelton & B.G.S. Geach. University of KwaZulu-Natal Press, Scottsville, South Africa.

Madubansi, M. & C.M. Shackleton. 2006. Changing energy profiles and consumption patterns following electrification in five rural villages, South Africa. *Energy Policy* 34(18):4081–4092. dx.doi.org/10.1016/j.enpol.2005.10.011

Madubansi, M. & C.M. Shackleton. 2007. Changes in fuelwood use and selection following electrification in the Bushbuckridge lowveld, South Africa. *Journal of Environmental Management* 83(4):416–426. dx.doi.org/10.1016/j.jenvman.2006.03.014

Motulsky, H. 2005. *Graph-Pad Prism 4 Statistics Guide: Statistical analyses for laboratory and clinical researchers*. GraphPad Software Inc., San Diego, California, U.S.A.

Mucina, L. & M.C. Rutherford. 2006. *The Vegetation of South Africa, Lesotho and Swaziland.* South African National Biodiversity Institute, Pretoria, South Africa.

Nichols, G. 2005. *Growing Rare Plants: A practical handbook on propagating the threatened plants of southern Africa*. Southern African Botanical Diversity Network Report No. 36. SABONET, Pretoria, South Africa.

Obiri, J., M. Lawes & M. Mukolwe. 2002. The dynamics and sustainable use of high-value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management* 166(1–3):131–148. dx.doi.org/10.1016/S0378-1127(01)00665-X

Shackleton, C.M. 1998. Annual production of harvestable deadwood in semi-arid savannas, South Africa. *Forest Ecology and Management* 112(1–2):139–144. dx.doi.org/10.1016/S0378-1127(98)00321-1

Shackleton, C.M. & S.E. Shackleton. 2006. Household wealth status and natural resource use in the Kat River valley, South Africa. *Ecological Economics* 57(2):306–317. dx.doi.org/10.1016/j.ecolecon.2005.04.011

Shackleton, C.M., S.E. Shackleton, E. Buiten & N. Bird. 2007. The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. *Forest Policy and Economics* 9(5):558–577. dx.doi.org/10.1016/j.forpol.2006.03.004