Forests, Trees and Livelihoods, 2002, Vol. 12, pp. 209–219
1472-8028 $10

FUEL WOOD VALUE INDEX OF WOODY TREE SPECIES FROM MAMLAY WATERSHED IN SOUTH SIKKIM, INDIA

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SUMMARY

Wood attributes such as calorific values, wood density, moisture and ash content of 66 woody (12 subtropical and 54 temperate) species from temperate and sub-tropical natural forest of Mamlay Watershed, Sikkim, India, were examined and used for estimating a fuel wood value index (FVI). The rankings as fuel wood by the local community and by their wood attributes of a sub-set were compared. Among the species highly valued by the local people, *Castanopsis tribuloides, Quercus lineata* and *Q. lamellose* showed high FVI values; *Eurya acuminata,* and *Cinnamomum impressinervium* with moderate preference scores also had lower FVI values. *Andromeda elliptica* and *Engelhardtia* sp. were ranked lower by local people than was expected on the basis of their FVIs. Both the FVI value and community preference should be used in assessing species' value for afforestation and management.

Key words: Sikkim, fuel wood value index, revegetation.

INTRODUCTION

In many mountainous areas, fuel wood coming from the natural forest is the only source of energy available to poor people (Purohit and Nautiyal 1987, Thapa and Weber 1990). It is simple to collect and use (Eckholm *et al.* 1984, Blaikie 1985), and other commercial sources of energy are beyond their reach due to difficulties of access, high prices and limited supply (Sharma *et al.* 1992). Most of the mature tropical forests have been lost during the past century, often due to unsustainable levels and ways of exploitation (Brown and Lugo 1982, Brown *et al.* 1991, Thapa and Weber 1990, WRI and IIED 1987). In the Himalayas, depletion of forest resources has directly aggravated the pressures on rural livelihoods through shortage of fuel wood (Thapa and Weber 1990).

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Paper first submitted 11.5.01; amended version accepted 24.10.01

Sikkim has been meeting and satisfying the fuel wood resources need of majority of the population, but evidence of a decline in forest species number and composition is emerging. The substantial increase in population and irrational use of natural resources have resulted in lowering of the forests' quality and fuel shortages; as a result, people have started using less valued species as fuel wood (Sundriyal and Sharma 1996). The selective use of a few valued species have resulted in a steady decrease in the stocking of many of the preferred fuel wood species in the natural forest (Sharma *et al.* 1992). Accounts of the wood properties for many of the widely used fuel wood tree and shrubs in other parts of the Himalaya are available (Krishna and Ramaswamy 1932, Singh and Khanduja 1984, Singh *et al.* 1984, Purohit and Nautiyal 1987). However there has been little effort to assess the fuel wood characters of forest species from the Sikkim Himalaya. The assessment of wood characters is important in order to select useful species for revegetating the wastelands and degraded forests to meet future fuel requirements. In hilly regions, watersheds are regarded as functional units for sustainable management of resources, so the present study was located in the Mamlay watershed which is representative of the eastern Himalaya (Sharma *et al.* 1998). It focused on 20 commonly preferred species and listed them according to the preference ranking of the local community. The wood properties of 12 sub-tropical and 44 temperate species were screened and compared with the 20 preferred fuel wood species in order to identify those with a high potential for use as fuel wood and recommended them for use in reafforesting degraded land in the area.

THE MAMLAY WATERSHED

The Mamlay watershed is located in the south district of Sikkim state (27°10″8′ to 27°14″16′N and 88°19″53′ to 88°24″43′ E) having an area of 30.14 km^2. The watershed has an altitudinal range of 300-2650 m above m.s.l. and includes 34 villages covering 62% area under agriculture, 12% under forest, 5% pasture land, 3% barren land and 18% under cultural wasteland (Sharma *et al.* 1992). The forest under investigation forms the north-east and north-west boundary of the watershed, is at a higher altitude than all agricultural land and, therefore, is of significant importance for the stability of the area (Sundriyal and Sharma 1996).

Two important forest types were recognized, namely (i) sub-tropical natural forest and (ii) temperate natural forest (Sharma *et al.* 1992, Sundriyal *et al.* 1994, Sundriyal and Sharma 1996). Sub-tropical natural forest is located at lower elevations of 400-1050 m and the temperate natural forest at 1050-2650 m above m.s.l. The sub-tropical forest is dominated by *Shorea robusta*, *Castanopsis indica*, *Castanopsis tribuloides* and *Schima wallichii*. The details of vegetation of this forest are already available (Sundriyal *et al.* 1994). The two most dominant canopy tree species are *Quercus lamellosa* and *Castanopsis tribuloides* in the temperate forest and two sub-canopy species are *Eurya acuminata* and *Symplocos theifolia*. Information on the vegetation structure and anthropogenic pressure of this temperate forest has been presented by Sundriyal and Sharma (1996).

MATERIALS AND METHODS

Matrix ranking on the preference of fuel wood species by the local community was done using a Participatory Rural Appraisal (PRA) technique (Pretty *et al.* 1995, Jain *et al.* 1999) in which the highest scores were associated with the highest preference, and vice versa (Jain *et al.* 1999). The exercise was conducted with a group of 20–30 individuals in an informal gathering. A trained person from the research group facilitated the villagers in the exercise. Villagers were asked to list the fuel wood species they use in their daily chores. The listed species were arranged in the first column as well as along the first row of a matrix box. People were asked to compare two given species at a time for their preference. The preferred species were noted and the number of time a species was preferred was summed to get its score. The score information was checked with four old villagers for its authentication.

The wood attributes – energy value, moisture and ash content, wood density and biomass:ash ratio – of 66 woody (12 subtropical and 54 temperate – including 14 of the 20 species chosen by the local people) species were determined using methods given by Anderson and Ingram (1993). Wood samples from branches measuring more than 12 cm diameter were collected and brought to laboratory within 24 hrs in airtight polybags.

- The fresh weight of the samples were taken;
- they were then dried in a hot air oven at 70° C for 24 hours; their dry weights were recorded after the samples showed constant weight.
- These dry and fresh weights were used to calculate moisture content.
- The biomass-ash ratio was calculated by dividing dry weight by ash weight.
- The dried sample were used to determine volume by the water displacement methods.
- The dried samples were milled in an electric grinder and passed through 2 cm mesh sieve. The ash content was determined by burning a weight amount in a muffle furnace at 550 C for 3 hrs.
- Energy (calorific) values were estimated using an oxygen bomb calorimeter following the method given by Leith (1975).
- A Fuel wood Value Index (FVI) was estimated using energy value, wood density, ash content and moisture content and applying the formulae developed by Purohit and Nautiyal (1987).

$$\text{FVI} = \frac{\text{Calorific value (kJ/g)} \times \text{density (g/cm}^3)}{\text{Ash content (g/g)} \times \text{Moisture content (g/g)}}$$

RESULTS

Species preference

Among the 20 widely used fuel wood tree species, *Quercus lamellosa* ranked first according to preference of the local people with the highest score of 19, followed by *Q. lineata* and *Castanopsis tribuloides* (Table 1). Interestingly, no sign of *Q. lamellosa* extraction from the forest was recorded whereas *C. indica, C. tribuloides* and *Schima wallichii* from the subtropical forest and *Michelia exelsa* and *Engelhardtia* sp. from the temperate forest showed irregular diameter class structures – probably a result of illicit extraction (Sundriyal *et al.* 1994, Sundriyal and Sharma 1996). In the preference hierarchy, the least preferred species were *Rhus succedanea, R. semialata,* and *Dendrocalamus* sp. suggesting poor fuel wood quality.

Fuel wood characteristics

The fuel wood characteristics of the 12 tropical and 54 temperate tree species are given in Table 2.

Our results for **calorific value** were below the bottom end of the range (9.03 kJ/g in *Eriobotrya petiolata*) that had been reported by earlier workers from

TABLE 1

Matrix ranking scores and preference ranking of 20 widely used fuel wood species from the Mamlay Watershed, Sikkim.

Botanical name	Local name	Rank	Score	FVI
Quercus lamellosa Smith.	Buk	I	19	3860.7
Quercus lineata Blume.	Phalant	II	18	3539.6
Castanopsis tribuloides A.DC.	Musre katus	III	17	1469.1
Eurya acuminata DC.	Jhingun	IV	15	1358.6
Drypetes lancifolia Pax. & K. Hoffm.	Hare	IV	15	–
Unidentified	Kande	V	13	–
Viburnum sp.	Asare	V	13	–
Cinnamomum impressinerium Meissn.	Sisi	VI	12	982.8
Andromeda elliptica Sieb.& Zucc.	Angeri	VI	12	3933.8
Leucosceptrum canum Sm.	Ghurpis	VII	10	1027.8
Symplocos theifolia Don.	Kharane	VIII	9	713.4
Maesa chisia Don.	Bilaune	IX	8	429.9
Jambosa sp.	Ambakey	IX	8	–
Schima wallichii Choisy.	Chilalune	X	6	889.6
Albizzia procera Benth.	Seto siris	XI	5	291.6
Macaranga pustulata King.	Malata	XII	4	672.6
Engelhardtia sp.	Aule mahuwa	XIII	3	1883.0
Rhus succedanea Linn.	Rani bhalayo	XIV	2	594.8
Rhus semialata Murr.	Bhakimlo	XV	1	693.1
Dendrocalamus sp.	Bans	XVI	0	–

Garwal Himalaya and other parts of the Central Himalaya (Nautiyal and Purohit 1988, Purohit and Nautiyal 1987). *Engelhardtia* sp. among the sub-tropical and *Rhododendron arboreum* among the temperate species, ranked highest in calorific value, but *R. arboreum* had the lower ash and moisture content. *Engelhardtia* sp. was followed by *Schima wallichii*, *Castanopsis hystrix* and *Acer oblongum*.

Moisture content varied from 33% (*Rhus semialata*) a temperate forest species to 64% (*Schima wallichii*) in a sub-tropical species.

Many of the sub-tropical species had **wood density** below 0.6 $g.cm^{-3}$; *Schima wallichii* was exceptional with a density of over 0.8 g/cm^3. The wood of *Symingtonia populnea* was the densest (0.89) among the temperate species followed by *Quercus lamellosa*, *Castanopsis tribuloides* and *Machilus gammieana*.

Ash contents were >1% on most of the species (85%) and only about 15% species showed <1% ash content; even these 15% showed lower ash contents compared to those given in reports by earlier workers (Natutiyal and Purohit 1988, Purohit and Nautiyal 1987).

Among the temperate species, *Prunus nepaulensis* showed the highest **biomass/ash ratio** (422) followed by *Rhododendron arboreum* (191), *Andromeda elliptica* (122) and *Quercus lineata* (108) due to their low ash contents. For the rest of the species, the ratio remained below 100.

The majority of the temperate species possessed high energy value and high density as reported by Purohit and Nautiyal (1987). In general, woods having high calorific values, high density, low ash and low moisture contents are good fuel wood species, although *Acer campbellii*, *Machilus gammieana*, *Schima wallichii* and *Macaranga pustulata*, all of which show high calorific values, high density and low moisture, are not so promising due to their high ash content. Among the 66 species, only 11 species, all from the temperate forest, with comparatively high calorific values, high density, low moisture and low ash contents had **Fuel wood Value Indices** over 2000. Among these, *Rhododendron arboreum* showed the highest FVI followed by *Prunus nepaulensis*, *Symingtonia populnea*, *Andromeda elliptica*, *Quercus lamellosa* and *Q. lineata*.

The field survey and participatory inventory data revealed that the Mamlay community prefers fuel wood with high wood density and which burns for a long time with constant heat. They realised that the woods with lesser amount of ash contents are better in quality.

The results of a stepwise regression analysis of community preference scores against the wood characters revealed that among the six characters, two of them showed significant partial regression coefficients. Wood density and ash content together explained 75% of the variation (Table 3).

DISCUSSION

The Mamlay watershed forest is under increasing biotic pressure with high fuel wood demand (Sundriyal *et al.* 1994). *Eurya acuminata, Viburnum* sp. *Cinnamomum impressinervium* with moderate preference scores are commonly

TABLE 2

Wood energy, density, ash and fuel wood value index (FVI) of 66 woody tree species of Mamlay Watershed. Bold species are listed from Table 1

Botanical name	Local name	Energy value (kJ/g)	Moisture (%)	Biomass/ash ratio	Density (g/cm^3)	Ash (%)	FVI
Rhododendron arboreum Smith.	Lali gurans	19.53	34	191	0.64	0.33	11091.7
Prunus nepaulensis C.K. Schn.	Arupate	17.73	48	422	0.52	0.23	8425.3
Symingtonia populnea R. Br.	Pipli	18.73	51	30	0.89	0.81	4033.1
***Andromeda elliptica* Sieb & Zucc.**	Angeri	18.75	39	122	0.56	0.69	3933.8
***Quercus lamellosa* Smith.**	Bajrant	18.04	43	76	0.86	0.93	3860.7
***Quercus lineata* Blume.**	Phalant	20.21	47	108	0.64	0.77	3539.6
Cinnamomum obtusifolium Nees.	Bhaley jhigune	17.34	47	91	0.51	0.69	2723.9
Phoebe lanceolata Nees.	Jhankri kath	16.06	44	28	0.47	0.67	2554.4
Prunus cerasoides Don.	Paiyun	19.82	44	48	0.46	0.82	2511.0
Elaeocarpus sikkimensis Mast.	Bhadrase	19.57	48	56	0.46	0.82	2300.4
Betula cylindrostachys Wall.	Saur	18.91	56	36	0.67	1.07	2102.5
Castanopsis indica A.DC.	Dhalne katus	17.84	38	70	0.62	1.46	1984.4
Rhododendron falconeri Hk.f.	Chimal	19.49	49	33	0.62	1.28	1922.0
Engelhardtia sp.*	Aule Mahuwa	19.80	44	48	0.48	1.15	1883.0
Juglans regia Linn.*	Okhar	18.93	47	44	0.67	1.44	1864.7
Acer oblongum Wall.*	Phirphire	17.78	35	50	0.67	1.86	1855.9
Machilus gammieana King.	Lapche kaula	16.18	39	50	0.71	1.62	1835.1
Quercus fenestrata Roxb.	Arkhaulo	19.83	46	45	0.53	1.43	1588.1
Acer campbellii Hk.f.&T.	Kapase	19.23	34	27	0.62	2.33	1503.3
***Castanopsis tribuloides* A.DC.**	Musre katus	18.84	51	25	0.78	1.98	1469.1
Spondias axillaris Roxb.	Lapsi	17.47	44	27	0.58	1.61	1444.0
***Eurya acuminata* DC.**	Jhingni	18.46	48	62	0.53	1.49	1358.6
Castanopsis hystrix A.DC.*	Aule katus	17.83	47	41	0.49	1.45	1284.6
Michelia lanuginosa Wall.	Phusre chanp	15.27	41	60	0.52	1.62	1207.0
Beilschmiedia roxburghiana Nees.	Tarsing	16.48	52	34	0.64	1.73	1180.0
Celtis tetrandra Roxb.*	Khari	14.14	36	54	0.69	2.31	1176.7
Nyssa sessiliflora Hk.	Lek chilaune	15.84	45	46	0.44	1.43	1094.1

Edgeworthia gardneri Meissn.	Argeli	16.15	35	33	0.42	1.77	1089.5
***Leucosceptrum canum* Sm.**	Ghurpis	14.63	40	39	0.62	2.23	1027.8
Myrica sp.	Kaphal	15.74	42	33	0.57	2.09	1025.0
Cinnamomum cecidodaphne Meissn.	Malagiri	19.23	43	44	0.47	2.11	1005.8
***Cinnamomum* impressinervium Meissn.**	Sisi	14.57	41	45	0.41	1.48	982.8
Eurya sp.	Lekh jhinguni	17.16	45	34	0.68	2.68	969.5
Glochidion acuminatum Muell.	Lathi kath	17.96	57	32	0.69	2.3	953.0
Terminalia belerica Roxb.*	Harra	13.12	53	30	0.52	1.35	945.1
Symplocos sp.	Rasuphal	14.18	36	22	0.61	2.61	931.9
Cinnamomum tamala Nees.	Tejpatta	15.86	37	34	0.56	2.66	900.8
Schima wallichii Choisy.*	Chilaune	18.86	64	25	0.81	2.69	889.6
Viburnum cordifolium Wall.	Asare	17.00	49	33	0.57	2.42	816.3
Eriobotrya petiolata Hk.f.	Maya	9.03	43	51	0.69	1.8	814.4
Michelia cathcartii Hk.&T.	Tite chanp	13.76	47	15	0.52	2.1	731.7
***Symplocos theifolia* Don.**	Kharane	13.15	53	48	0.46	1.59	713.4
Machilus edulis King.	Kaula	14.75	39	21	0.64	3.37	709.4
Casearia glomerata Roxb.	Badkunle	13.58	48	12	0.54	2.18	699.5
***Rhus semialata* Murr.**	Bhakimlo	14.14	33	24	0.43	2.66	693.1
Walsura tubulata Hiern.	Phalamen	14.63	54	41	0.66	2.57	691.2
Alnus nepalensis D. Don.	Uttis	17.30	46	17	0.32	1.77	673.5
***Macaranga pustulata* King.**	Malata	20.06	54	28	0.41	2.25	672.6
Litsaea elongata Wall.*	Thulo pahenle	13.27	51	16	0.52	2.08	644.8
***Rhus succedanea* Linn.**	Rani bhalayo	17.99	42	27	0.37	2.64	594.8
Erythrina arborescens Roxb.	Phaledo	17.99	60	24	0.33	1.71	580.5
Actinodaphne sikkimensis Meissn.	Singsinge	13.21	46	34	0.54	2.85	542.7
Evodia fraxinifolia Hk.f.	Khanakpa	13.37	62	16	0.46	1.87	530.1
Machilus odoratissima Nees.	Lali kaula	14.62	53	16	0.62	3.28	520.6
***Engelhardtia spicata* Blume.**	Mahuwa	17.75	52	20	0.45	2.98	515.3
Endospermum chinense Benth.	Seti kath	13.94	44	20	0.58	3.72	491.0
Ehretia wallichiana Hk.f.& T.	Lek baer	12.37	44	30	0.47	2.69	490.7

Table 2 continued on page 216

Table 2 continued

Botanical name	Local name	Energy value (kJ/g)	Moisture (%)	Biomass/ ash ratio	Density (g/cm^3)	Ash (%)	FVI
Symplocos sumuntia Ham.	Kholmen	12.46	54	33	0.56	2.68	480.5
Litsea elongata Wall.	Kali pahenli	13.59	58	11	0.35	1.83	448.2
***Maesa chisia* Don.**	Bilaune	13.05	53	26	0.51	2.95	429.9
Duabanga sonneratoides Ham.*	Lampate	17.18	59	17	0.43	3.02	414.4
Schefflera impressa Harms.	Bhalu chinde	14.14	51	13	0.44	3.22	377.7
Ostodes paniculatus Blume.*	Bepari	17.41	59	15	0.43	3.62	348.0
Echinocarpus dasycarpus Benth.	Gobre	12.82	52	25	0.42	3.11	333.6
Albizzia procera* Benth.	Seto siris	10.03	45	15	0.44	3.35	291.6
Vitex heterophylla Robx.*	Panchpate	12.38	61	14	0.49	3.72	266.9

*subtropical species

TABLE 3

Step-wise Regression analysis showing relationship between people's score and other wood attributes.

Dependent Variable SCORE
R = 0.907 R-Square = 0.823

Effect	Coef-ficient	Std Error	Std Coef	Tol.	DF	F	P(2 Tail)
1 Constant							
2 ENERGYVALUE	−0.486	0.350	−0.247	0.62369	1	1.929	0.198
3 MOISTURE	0.222	0.149	0.224	0.87562	1	2.234	0.169
4 BIOMASSASH	0.043	0.054	0.225	0.24239	1	0.627	0.449
5 DENSITY	27.137	6.931	0.625	0.77174	1	15.331	0.004
6 ASH	−2.430	2.233	−0.341	0.19971	1	1.184	0.305

R = 0.865 R-Square = 0.749

Effect	Coefficient	Std Error	DF	F	P(2 Tail)
1 Constant	−0.749	5.293			
5 DENSITY	27.937	7.107	1	15.451	0.002
6 ASH	−2.501	1.165	1	4.608	0.053

used even though their FVI suggest only moderate quality (Table 2). It is curious that *Rhododendron arboreum* , having the highest FVI is not used by the community in the Mamlay watershed even though it is extensively used elsewhere in Sikkim where the availability of alternative fuel wood species are limited (Chettri 2000). This could be due to a combination of availability of other alternative species in the area and custom – possibly related to religious practices. Though widely used fuel wood species such as *Castanopsis tribuloides* and *Eurya acuminata* are still abundant in the Mamlay watershed (Sundriyal and Sharma 1996), others such as *Quercus* spp., *Castanopsis* spp. and *Schima wallichii* are under pressure

Farmers' preference scores for *Castanopsis tribuloides, Quercus lineata* and *Q. lamellosa* were matched with high FVIs. It is evident from the regression that people's preference is associated with density and ash content. From the interviews, it emerged that a compact and heavy wood with low ash content when burnt that was easy to collect and split into pieces, was thought to make the best fuel wood. This could be the explanation why their preference scores were lower than expected for *Engelherdtia spicata* and *Andromeda elliptica*. Our observation revealed that *Engelherdtia spicata* has a low wood density, is comparatively light due to its porous structure and gives off noxious fumes. *Andromeda elliptica* is difficult to cut and split into pieces due to its fibrous, interlocked wood structure.

The data on the FVI indicate that it is extremely sensitive to low moisture and ash content; this, coupled with the regression analysis that suggests users' preference is mainly associated with high density, indicate that the FVI alone is an imprecise guide to fuel wood quality.

High extraction pressure, attributed to a rising sustained demand for fuel wood, has caused deforestation and accelerated the soil erosion process; in turn this has further reduced soil fertility and productivity (Rai and Sharma 1998). Effective forest management and conservation practices cannot be implemented as adequate fuel alternatives are not available in the area. The development of alternative fuel supplies [for example from plantations and subsidized supplies of kerosene and liquified petroleum gas (LPG)], coupled with the adoption of an improved code of environmental conservation ethics by both the community and the responsible authorities, could help to solve the problem of forest degradation. Initiation of conservation activities among the communities with participatory monitoring of resources and wildlife would strengthen conservation in the area.

A proper management strategy for the restoration of these forests using high quality fuel wood species is necessary. Forest managers should take the initiative in afforestation with the help of villagers by providing them saplings of high quality fuel wood species. The FVI tool along with participatory preference listing may be useful in choosing species as there are likely to be some location- or community-specific preferences, as observed for *Rhododendron arboreum.*

ACKNOWLEDGEMENT

The authors are thankful to the Director, G. B. Pant Institute of Himalayan Environment and Development for providing necessary facilities. Dr Rita Sharma helped during the laboratory analysis. Facilities provided by ATREE-EHP are highly acknowledged.

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