Energy for Sustainable Development 24 (2015) 9–18

Contents lists available at ScienceDirect

Energy for Sustainable Development

Developing the fuelwood economy of Papua New Guinea

Ian K. Nuberg *

School of Agriculture, Food and Wine, Waite Campus, University of Adelaide, PMB 1 Glen Osmond, South Australia 5064, Australia

ARTICLE INFO

Article history:
Received 4 June 2014
Revised 30 October 2014
Accepted 31 October 2014
Available online xxxx

Keywords:
Fuelwood
Survey
Papua New Guinea
Small business

ABSTRACT

This paper describes the fuelwood economy of Papua New Guinea (PNG) based on a survey of domestic users ($n = 3994$), commercial and industrial users ($n = 66$) and fuelwood vendors ($n = 157$). The survey period (2009) covered urban and rural, coastal and highland districts of known fuelwood-stress. The survey region represents 11% of the national population. It reveals that the fuelwood economy has a relatively flat structure with a very short and direct supply chain. Fuelwood is regularly or occasionally used by 85% of the population for domestic and commercial cooking, even in urban areas where there is good access to electricity and other energy sources. Proportions of the population selling fuelwood at some time in the survey period were 3% and 10% of urban and rural populations respectively. Those generating an income using fuelwood were 26% and 58% respectively. Fuelwood consumption is estimated to be 1.8 m^3/person/year which is 6 times greater than the average of south and south-east Asian countries. It is estimated that 2.08 million m^3/y of fuelwood is freely collected for domestic use in the survey region, while the amount traded was USD7.14 million. The survey provides details of regional variations in fuelwood consumption, gender relations, income generation, and conflict associated with fuelwood, tree planting activity and attitudes to the need for woodlots. It describes and quantifies fuelwood flows from various sources to users and argues the point that the impact of fuelwood collection on forests is only localised. The fuelwood economy is largely informal with no public engagement in supply, marketing, distribution, pricing, and taxation. This paper argues the case for a national fuelwood policy which will encourage the private sector to invest in fuelwood trade and create economies of scale while still protecting smaller informal actors.

Introduction

Papua New Guinea (PNG) is a country with great potential for economic and social development based on its natural resources. Its export income of approximately USD 4.8 billion/y is largely generated from mineral wealth (75%) followed by agriculture (19%), forest extraction (4%) and marine products (2%) (PNG, 2014). Yet the average annual income of the waged population is USD 4244/y and the minimum wage is only USD40/week (USDS, 2013). The vast majority of the population do not benefit directly in terms of employment in these sectors and about 85% still live in rural areas and depend on customary land for their livelihoods (Vegter, 2005). While many people have access to land for farming and growing trees for profit, these sectors are poorly developed resulting in under employment for much of the population.

There is a need to improve the livelihood opportunities based on the forest and land resources available to rural people. Fuelwood is the primary energy source for cooking and heating especially in the highlands where over 40% of the population lives (Allen et al., 2001). It is a crucial component of the domestic energy market; it is also a very easy market to enter as a small business. While alternative energy sources are available (electricity, kerosene, gas) they are not universally available and affordable. Fuelwood will continue to play a major role in the domestic energy economy of PNG for the foreseeable future. Apart from an unsuccessful attempt to establish the common use charcoal stoves in the 1980s (Harris, 1979; Gamser and Harwood, 1982; Gamser and Harwood, 1983) there has been no attempt to develop the fuelwood-based energy sector in PNG.

While there have been comprehensive studies of fuelwood flows and markets of 16 Asian nations under the Regional Wood Energy Development Programme of the FAO in the 1990s (FAO, 1997; FAO-RWEDP, 1999), there have been few attempts to understand the fuelwood economy of PNG. Such attempts have been as part of a broad national economic analysis (e.g. World Bank Poverty Assessment Program cited in (Bourke, 1997)), FAO assessment (Brown, 1997), regional analysis of livelihoods (Hanson et al., 2001), or a small focussed studies on urban household energy use (Gamser, 1980) or rural household fuelwood use (Murphy, 2006)

The casual visitor to PNG might be forgiven for believing that there is an abundance of fuelwood naturally available. 72% of the country is under forest or other wooded land. There are approximately 4.5 ha of forest for each person in PNG, and about 97% of land in PNG is under customary tenure (FAO, 2010). However the population is not evenly distributed across the landscape. There are large aggregations around

* Tel.: +61 8 8313 0527.
E-mail address: ian.nuberg@adelaide.edu.au.

http://dx.doi.org/10.1016/j.esd.2014.10.006
0973-0826/

Port Moresby and Lae, and the 40% of the population in the highland provinces are largely clustered in the cleared valleys. The fact that fuelwood vendors are a common feature of urban and rural market places indicate that many people do not have access to these trees for fuel. Even that fuelwood that is collected for "free" is a diminishing and highly contested resource (Murphy, 2006).

PNG has the problem of many resource-rich developing countries; a two-tiered economy where a small proportion of the population benefits from the extractive industries (mining and forestry), plantation industries and the public sector that is supported by them, while the majority have few opportunities at income generation beyond cash cropping and opportunistic service sector (e.g. market place hot food vending). Hanson et al. (2001) estimated that about 10% of the population also engage in selling fuelwood at some time and that it is a relatively easy market to move into. Apart from sawmill-offcuts there is no fuelwood available from forest logging or plantations. The market appears to be entirely informal and based on collected wood; i.e. not specifically purpose-grown. It is proposed that the fuelwood sector can be developed with more efficient, value-adding supply chains that provide livelihoods for small entrepreneurs. Much more knowledge about this sector is required to test this proposition.

Therefore, the aim of this paper is to present a quantified description of the fuelwood economy of PNG, with a view to understanding the potential for developing a sustainable domestic energy market that provides livelihood opportunities for a broad section of the population. This description is based on analysis of results of a large survey of domestic and commercial fuelwood users, fuelwood vendors and other stakeholders in the fuelwood sector.

The survey was undertaken in 2009 and focussed on regions that were known to be fuelwood-stressed; i.e. where there are strong fuelwood markets and where it is known to be conflict arising from competition for gathered wood. While fuelwood is used across the whole nation, in both urban and rural settings, the main rural districts where it is recognised as a significant part of the local economy are found in the highland provinces of Chimbu, Enga and the Eastern, Western and Southern Highlands. Many of these districts have been assessed to be under significant agricultural pressure and overall relative social disadvantage (Hanson et al., 2001).

The survey had 3 components: a large questionnaire survey of domestic users and vendors, a case-study monitoring activity; and semi-structured interviews of industrial and commercial operations using fuelwood and other fuelwood stakeholders. The complete results of the survey can be found in Nuberg (2013b).

Method

A set of three questionnaire surveys were undertaken over two periods October–December 2008 and March–May 2009 of 2673 domestic urban users of fuelwood, 1321 domestic rural users and 157 fuelwood vendors. In addition the fuelwood use of 36 urban and rural case study households was monitored over a 2-week period and semi-structured interviews undertaken with 66 commercial and industrial users of fuelwood.

The survey was designed in a facilitated participative process at the PNG Forest Research Institute (FRI) in Lae. The survey design focused on areas where there is known fuelwood stress in PNG. These areas were determined to be the National Capital District (NCD) around Port Moresby, the city of Lae and its rural hinterland, the city of Mt Hagen and the rural areas of Mt Hagen District of the Western Highlands Province, Chuave District in Chimbu and Henganofi District in the Eastern Highlands (Fig. 1). In terms of populations, the provinces from which these districts are selected represent 36% of the national population of 5,190,000 (NSO 2000). The actual districts represent about 10.6% of the national population.

Questionnaire sampling strategy

The stratification of the survey population was based on information from the most recent national census (NSO, 2000). Within each of the survey districts the appropriate sample size for each Local Level Government unit (LLG) or ward was determined on the basis of relative population. The census unit is the finest level in the census hierarchy and represents entities such as roads, hamlets, villages, compounds, barracks etc. Each of these wards had different numbers of census units. It was not feasible to survey all census units in a district so a further level of sample discrimination was necessary. For each district the key indicator used to segregate census units was "Proportion aged 10 years and over economically active". This indicator includes both males and females. The distribution of this indicator was separated into three equal thirds. An equal number of census units were randomly selected from each third of this distribution. The selected census units were allocated a sample size and identified on maps to be surveyed. In all, there were 55 sampling strata. Some of these were at the level of LLG/ward some were at the level of census unit.

Survey data collection and collation

The questionnaire surveys and case-study monitoring were administered by the Foundation for People and Community Development (FPCD), a national NGO with experience in survey work. Six professional FPCD staff were involved and they trained a further 35 interviewers to assist with the questionnaire surveys. The surveys were undertaken in the lingua franca *Tok Pisin* but recorded on survey forms in English. The interviewers worked in pairs for security reasons. They worked on either side of a road and called upon every third dwelling along the road. If no-one was home or declined the survey, the interviewer moved to the next house until a willing interviewee was found. The interviewers continued through the sample stratum like this until the requisite number of interviews were made for that sample stratum.

The Fuelwood Vendors survey was undertaken opportunistically during the second round. Vendors were generally approached as they were encountered on the street in the progress of the user surveys. The interviewers also visited all the known fuelwood markets in each sample stratum.

On completion of each round, the questionnaires were shipped to Adelaide and entered into a database in MicroSoft Access 7.

Questions asked in the survey

The nature of the questions asked are summarised in Table 1. Question 7 in the domestic user's surveys was critical for aggregated estimates of fuelwood consumption. Interviewees were asked to estimate how much fuelwood they had used in the week prior to being interviewed, and the week before that. They were shown a 5 or 10 kg bundle of firewood (or photograph equivalent) and asked how many of these they would have used.

Such re-called information provides 'guestimates' at best, so a subsample of 36 urban and rural households interviewed in the questionnaire survey was invited to participate in the case-study monitoring exercise. This exercise involved two 1-week periods of direct weighing, and recording of species, of all fuelwood consumed on a daily basis. This survey was undertaken by FPCD staff in April 2009.

The diversity of small commercial and industrial users of fuelwood, and stakeholders in the fuelwood economy, was such that semi-structured interviews were a more appropriate survey tool. The interviews were directed to gather: quantitative information about fuelwood use, in which case physical measurements were sometimes taken; qualitative information about problems and opportunities associated with fuelwood. These interviews were undertaken by FRI staff and included 42 hot-food vendors and bakeries along the Highlands Highway, 11

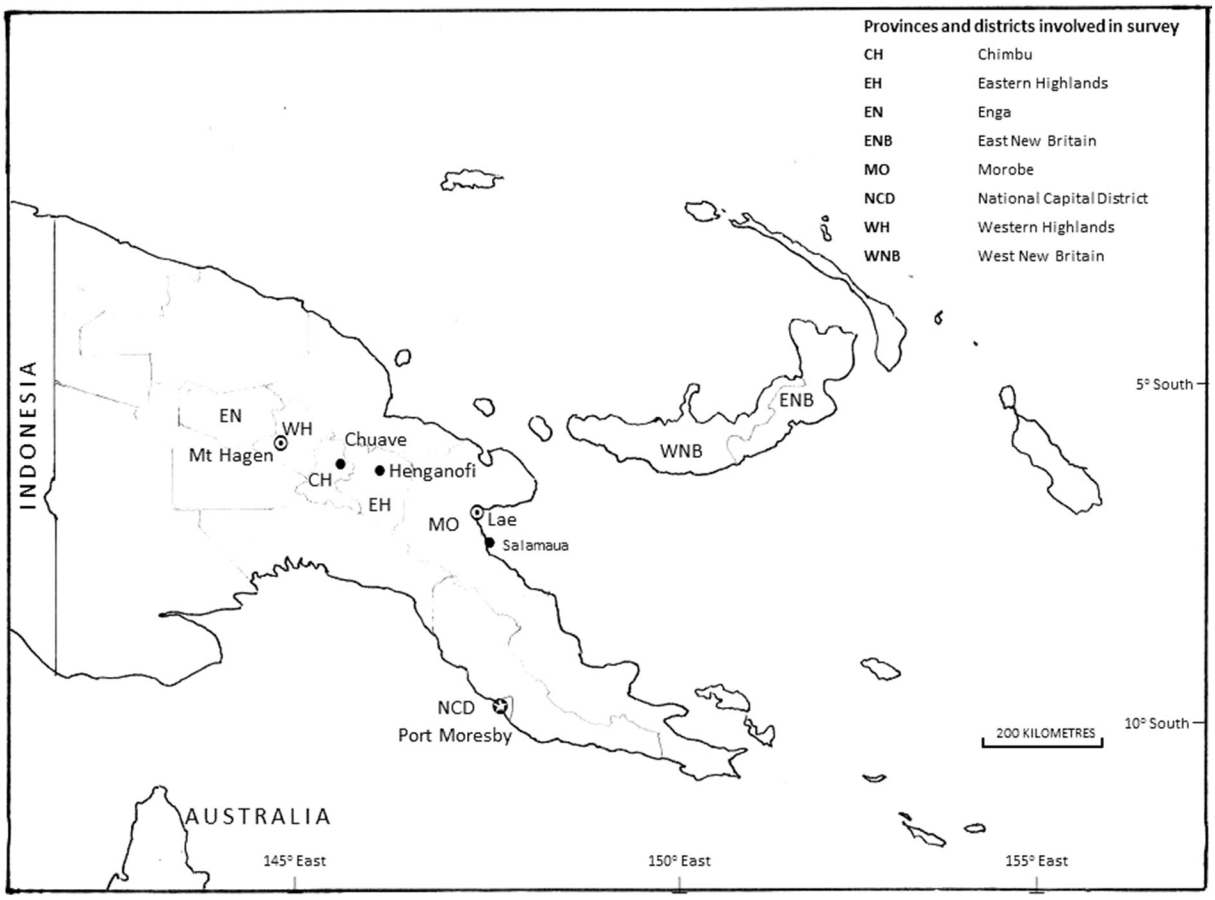

Fig. 1. Map of Papua New Guinea indicating survey regions.

lime burner communities along the Morobe coast, 12 oil palm, cocoa and copra factories in West and East New Britain Provinces and 1 tea factory in the Western Highlands. These interviewees were not necessarily in the fuel-stressed districts covered in the questionnaire survey.

Analysis

Estimates of aggregate fuelwood use and expenditure

The analysis of data included aggregate estimates of fuelwood expenditure and volume of freely wood collected. The estimate of annual expenditure on fuelwood across the fuelwood-stressed districts was determined using Eq. (1) (Table 2 explains terms used in equations).

$$E_A = \sum_{d=1}^{5}\left(\left(H\frac{e_r}{H_s}\right)\times 26 + \left(H\frac{e_o}{H_s}\right)\right)_d \quad (1)$$

The survey quantified the amount of fuelwood collected in terms of mass (see Q7 in Table 1). The annual tonnage of fuelwood collected across the 5 survey districts is the sum of the district totals, $M_{d,}$ which was calculated in Eq. (2).

$$M_A = \sum_{d=1}^{5}\left(\frac{H\times m_h\times 52}{1000}\right)_d \quad (2)$$

Weight to volume conversions were based on assumed basic density of 0.725 gm/cm^3 (FAO, 1993). This approximation was validated using the water-displacement method on the more common species found in the market, *Casuarina oligodon* (in highlands) and *Eucalyptus alba* (around NCD). The annual volume of fuelwood consumed by person in each survey district was estimated using Eq. (3).

$$V_d = \frac{m_d}{0.725\times H_d\times H_u} \quad (3)$$

Gender equity index

The interviewees were asked who collects and who buys fuelwood in their household, and this was analysed by a simple gender equity index. This was calculated as the ratio of the relative proportion of instances of female activity to instances of male activity, or

$$\textit{Gender Equity Index} = \frac{\textit{sum of reports of female activity in district}}{\textit{sum of reports of male activity in district}} \quad (4)$$

Within a survey district, if men and women share the load equally in collecting and buying fuelwood, i.e. a 1:1 ratio, then the index = 1.0. In the gender index used here, if there are more instances of men's activity then index <1, if women more active >1. A change in 0.1 units of the index reflects a change in 10% of the sample population.

Results and discussion

In this section, the core quantitative survey data is presented in Tables 3, 4 and 5 with supplementary data and information from the interviews in the text. The subheadings cover the main messages that emerge from the data and the significance of these is discussed. This is then followed by an integrated description of the fuelwood economy including a picture of woodflows in the survey region (Fig. 2). This figure

Table 1
Nature of the questions asked in the questionnaire surveys.

Q	Domestic users' surveys: urban and rural
1	Demographic details of interviewee (age and gender)
2	Nature of the environment where they live. Urban: housing, access to electricity, sealed roads; Rural: housing, surrounding vegetation, topography, road access, civic infrastructure.
3	Using fuelwood or not within previous 12 month period: domestic, commercial, ceremonial use.
4	Type of fireplace and seasonal variation in use.
5	Energy sources other than fuelwood, and for what purpose.
6	Decisions behind energy use: local regulations, access, cost, health, convenience, preference etc.
7[a]	Amount fuelwood used this week and preceding week. Is this normal?
8	Type and source of collected fuelwood, including collections per week.
9	Distance travelled in collection, including source of fuelwood.
10	Modes of fuelwood transport, including source of fuelwood.
11	Frequency and expenditure on purchased fuelwood: this week and preceding week. Is this normal?
12	Gender and age roles in fuelwood collection and purchase.
13	Using fuelwood to earn an income: e.g. food preparation, lime burning, selling fuelwood.
14	Change in access to fuelwood over last 2 and 10 year periods.
15	Activity in planting trees over last 2 and 10 year periods.
16	Conflict over access to fuelwood.
17	Need for local woodlots.
18	Preferred fuelwood species.
19	Knowledge and attitudes on charcoal.
	Fuelwood vendors' survey
1	Demographic details (age, gender, birth place and current residence).
2	Enterprise size based on volume of fuelwood on sale.
3	Location and permanency of selling point.
4	Frequency of selling activity and reasons for this.
5	Fuelwood source and arrangements with landholders.
6	Transportation to point of sale.
7	Buying and on-selling practice.
8[b]	Prices and weights of products on sale.
9	Annual income from selling and costs involved in selling fuelwood.
10	Able to grow trees to sell if so desired.
11	Problems associated with selling fuelwood.
12	Knowledge and attitudes on charcoal. Willingness to sell charcoal.

Not all questions are dealt within the presentation of results in this publication.
[a] Interviewees were shown a 5 or 10 kg bundle of firewood (or photograph) and asked how many of these they would have used.
[b] Bundles on sale were weighed with a 50 kg grocer's balance after vendor granted permission.

Table 2
Explanation and source of terms used in equations.

Term	Explanation	Source
D	Survey district (there are 5: NCD, Lae urban, Mt Hagen urban, Lae rural, Highlands rural)	Survey
E_A	Aggregate annual expenditure for the 5 surveyed districts	Estimate
e_r	Total expenditure on fuelwood for regular use in the 2 week survey period in the district	Survey
e_o	Total expenditure on fuelwood for occasional purposes in the survey year in the district	Survey
H	Total number of households in survey district	[1]
H_d	Average number of persons per household in survey district	[1]
H_s	Number of households interviewed in survey district	Survey
H_u	Number of households interviewed which use fuelwood in survey district	Survey
M_A	Aggregate annual mass of fuelwood collected for the 5 surveyed districts	Estimate
m_d	Estimated total annual mass of fuelwood collected in district (t/y)	Survey
m_h	Average mass of fuelwood collected per household per week in district (kg/household/wk)	Survey
V_d	Total annual volume of fuelwood collected in district (m^3/y)	Estimate
0.725	Mass:volume conversion ratio based on basic density, g/cm^3	[2]
26	Number of fortnights per year	
52	Number weeks in year	

Refs: [1] NSO, 2000, [2] FAO, 1993.

contains the estimates of volumes of fuelwood collected in each survey district and the value of fuelwood purchased as determined from Eqs. (1) to (3).

Fuelwood affects most of the population

Overall 85% of the surveyed population used fuelwood in the 12 months preceding the survey. Table 3 provides the regional breakdown. Virtually the whole rural and highland populations use fuelwood. In the NCD there is a moderate correlation ($R^2 = 0.6$) between the proportion of dwellings with access to power lines with the proportion of non-fuelwood users in each of the 9 NCD wards. However, even in wards with almost 100% access to electricity, 47% of inhabitants still used fuelwood in the survey year; this could be for regular cooking, for ceremonial and celebratory use, in small business or just in the event of power outages.

While domestic cooking is the most important use of fuelwood, 17% of the interviewed population cooks their food by other means. Only 4% of rural people use other energy for cooking. Alternative sources of energy were also used by 88% of fuelwood users. The most common response was to use kerosene for lighting, then the hierarchy went from gas for cooking, generators for appliances, then mains access. About 15% of the sample population had access to mains power and 30% access to generators, which may be communally owned in rural areas.

Considerable time and expense are involved in fuelwood procurement. In all the urban areas a many of the interviewees travelled between 1 and 3 km into the surrounding hills to gather fuelwood. The proportions were 27% in NCD, 32% in Lae and 32% in Mt Hagen. A further 11%, 25% and 2% respectively travelled more than 3 km into the surrounding hills and beyond. The average estimated distance travelled beyond 3 km was 10 km (range 4–30 km, $n = 175$). In rural areas 11% of interviewees travelled more than 3 km, mainly into the natural forest, their current gardens and bush fallows.

The most common form of transporting wood that was collected was on foot which accounted for 68% of respondents. Of the 32% of respondents who used vehicles to transport collected fuelwood, most of these used public transport (31%), their own car (29%), or had it delivered (22%).

The average expenditure per household on fuelwood for regular domestic use over a 2 week period was on average about US$10 with slightly higher amounts for rural buyers (Table 3 row 6). These estimates exclude purchases that were deemed for ceremonial and commercial uses. Table 3 highlights the strong regional differences in the purchasing population. In particular 53% of Mt Hagen urban residents, many of whom are settlers from other districts, do not have access to local trees through clan relationships. In comparison, the Lae and NCD urban samples include wards which are peri-urban and better treed than Mt Hagen. The proportions of fuelwood buyers in rural areas are much lower because these residents are largely on their own land (Table 3 row5).

Daily household fuelwood use was determined in two ways (Table 3 rows 18 and 19). The re-called information generated by the domestic surveys is compared with the daily measurement of fuelwood used by case-study households. The two data sets are within reasonable agreement, although it is clear that interviewees providing re-called information tend to underestimate their fuelwood use. The average daily fuelwood use across the monitored households was 24.8 kg/d. However, there was a considerable range in measurements from 2.2 to 97.4 kg/d, so the median value of 16.0 kg/d may provide a more conservative estimate.

Gender relations of fuelwood collection and purchase are traditional

When considering gender data from an interview survey it is important to describe the gender balance of the sample and the interview

Table 3
Core quantitative dimensions of fuelwood economy as determined by questionnaire surveys of domestic users, vendors and case study monitoring.

Regions of fuelwood stress surveyed		Urban			Rural	
		NCD	Lae	Mt Hagen	Lae	Highland[b]
	Population[a]	254,158	78,692	27,877	40,486	150,916
Row	Sample size	1868	558	247	285	996
1	% sample using fuelwood (FW) over past 12 months	73	90	87	98	100
2	Average frequency of FW gathering per week (Median?)	1.4	2.0	2.9	4.8	3.4
3	Average frequency of FW purchase per week	2.4	1.9	2.6	1.8	1.8
4	% user population buying over last 2 week	24	27	47	7	4
5	Number of buyers for every 100 users	33	27	53	7	3
6	Average spent over 2 weeks in PNG Kina [c] (USD)[d]	20.65 (9.06)	21.60 (10.04)	20.39 (9.48)	27.61 (12.83)	24.10 (11.20)
7	% FW users experienced conflict over access to FW	48	40	58	51	61–88
8	% FW users who have planted trees in past 2 years	44	25	54	83	96
9	% FW users expressing need for local woodlots	92	62	94	70	95
10	Gender equity index for fuelwood collection	1.0	0.9	0.6	1.1	0.9
11	Gender equity index for fuelwood purchase	1.0	0.7	0.7	0.5	0.5
12	% planted trees in the last 10 y	78	48	73	55	95
13	% FW vendors with access to land to grow trees	86	39	88	39	89
14	% sample travelling >3 km to gather FW[e]	6			11	
15	% domestic FW users also using fuelwood commercially	26			58	
16	% domestic FW users also selling fuelwood	3			10	
17	% for whom FW more difficult to access over past 2 y	65			41	
	Daily household fuelwood use					
18	Recalled data from domestic user surveys, kg/d	9.6	10.6	5.6	8.9	21.1
19	Daily monitoring of case study households over 2 weeks					
	Number of households monitored	13			23[f]	
	Average daily fuelwood use, kg/d	11.1			32.5	
	Median daily fuelwood use, kg/d	11.6			27.3	
	Aggregated estimates					
20	Volume collected m^3/person/yr	0.93	0.85	0.50	0.74	2.41
	Average over FW-stressed regions	1.8				
21	Total volume over FW-stressed regions million m^3/y	2.08				
22	Household expenditure for regular use USD/hh/yr [c]	250	261	247	333	291
	Average over FW-stressed regions	266				
23	Household expenditure for ceremonial use USD/hh/yr	112	52	65	84	118
	Average over FW-stressed regions	100				
24	Total over FW-stressed regions (USD million)	7.14				

[a] Population data from National Census 2000.
[b] Aggregate value for Mt Hagen, Chuave and Henganofi highland rural districts.
[c] These values reflect purchases for regular household use, as purchases > PGK100 for ceremonial and commercial use were excluded.
[d] 1.00 PGKina = 0.465 USD exchange rate at 2 April 2013. Values in brackets US dollar.
[e] 3 km is an arbitrarily chosen limit of easy access by foot from home.
[f] The rural case study households were all in the highlands and not around Lae.

team. The male:female ratio in the urban sample was 56:44 while the rural sample was 82:18. The interview team though largely male did include female interviewers; however, in rural areas the teams were usually pairs of males for security reasons. Even if there was a female in the pair, it was usually a male who represented the interviewed household. This was unavoidable in the context of PNG rural culture.

Table 4
Frequency of income categories in enterprises using or selling fuelwood.

Income in preceding 12 months		Enterprises using fuelwood to generate income[b]		Fuelwood vendors
		Urban (n = 2916)	Rural (n = 1028)	Urban and rural (n = 116)
In PGK	[a]In USD	% frequency	% frequency	% frequency
<100	<47	3	3	
100–499	47–232	36	24	[c]25
500–999	233–465	24	36	32
1000–4999	466–2325	22	32	35
5–10,000	2325–4650	6	2	6
>10,000	>4650	8	3	2
Average PGK	(USD)	3503 (1629)	1557 (724)	2326 (1081)
Minimum		20 (9)	30 (14)	60 (28)
Maximum		73,000 (33,945)	33,600 (15,624)	70,000 (32,552)
Standard deviation		8802 (4092)	2923 (1359)	7464 (3470)

[a] 1.00 PGKina = 0.465 USD exchange rate at 2 April 2013.
[b] Does not include lime burners.
[c] Lowest vendor income category <500 PGK.

Table 5
Core results from fuelwood vendors' survey.

Sample sizes	Overall $n = 157$. 89 urban + 68 rural; 60 lowland + 97 highland
Gender and age	83% were male and 49% in the 30–50 y age category
Location of operation	40% operate from their home village/city, 5% come in from village to sell in town, while 55% originate from another province and are selling in city using local sources.
Scale of operation	51% vendors presented <100 kg of wood for sale on non-permanent sites, while 33% were on semi-permanent sites
Frequency of operation	Twice as many fulltime vendors (5–7 days/week) than part-time (1–4 days/week), while 11% of the sample were larger suppliers to factories, commercial users etc. operating on an irregular basis
Source of fuelwood	46% of vendors source fuelwood from their own land, 24% collect from other sources and 22% buy some or all of their wood from landholders, 28% buy and on-sell to other wood vendors
Transport type	Fuelwood is delivered to point of sale by either local bus (42%) or foot (42%). 6% of vendors have the fuelwood delivered to them by a landowner.
Transport distance; average (maximum)	NCD 10 (25)km; Lae 3(5)km, Hagen 6 (30)km and EH/CH 23(40)km
Value of fuelwood for sale PKG/kg	NCD 0.30; Lae urban 0.49; Lae rural 0.58; Hagen urban 1.15, Hagen rural 1.04, EH/CH 0.33 Along the Highlands highway K0.25/kg

This should be kept in mind when interpreting the gender equity indices in Table 3 rows 10–11. It is possible that the rural data reflects unbalanced, positive self-reporting from male respondents.

The gender equity index showed that while males and females across all age classes share the responsibility of fuelwood collection and purchase equally in NCD, this is not so in other regions. For example, while males collect fuelwood more than women in Mt Hagen Urban (which may well be due to security reasons), the relationship is opposite in Lae Rural. In particular, in rural households men are twice as likely to buy fuelwood as women.

The gender relations of fuelwood collection and purchase in PNG do not appear to be as unbalanced as they are in other developing countries where it is a largely a woman's task (e.g. Anon, 1995; Raghupathi and Venkaiah, 2007; Larinde and Olasupo, 2011; Nizami, 2013). In some cases it is gender independent, such as rural Argentina (Cardoso et al., 2012).

The validity of this survey's results on gender equity can be tested against the only other study of gender relations in fuelwood collection in PNG (Murphy, 2006). This was a smaller, focussed survey ($n = 401$) with both urban (town settlement) and village subsamples to the southeast of Goroka, Eastern Highlands. The sample had a slight female majority because the interviewers were local. Even in this survey 45% of the collection of fuelwood was done by males in the household (i.e. gender equity index = 1.2).

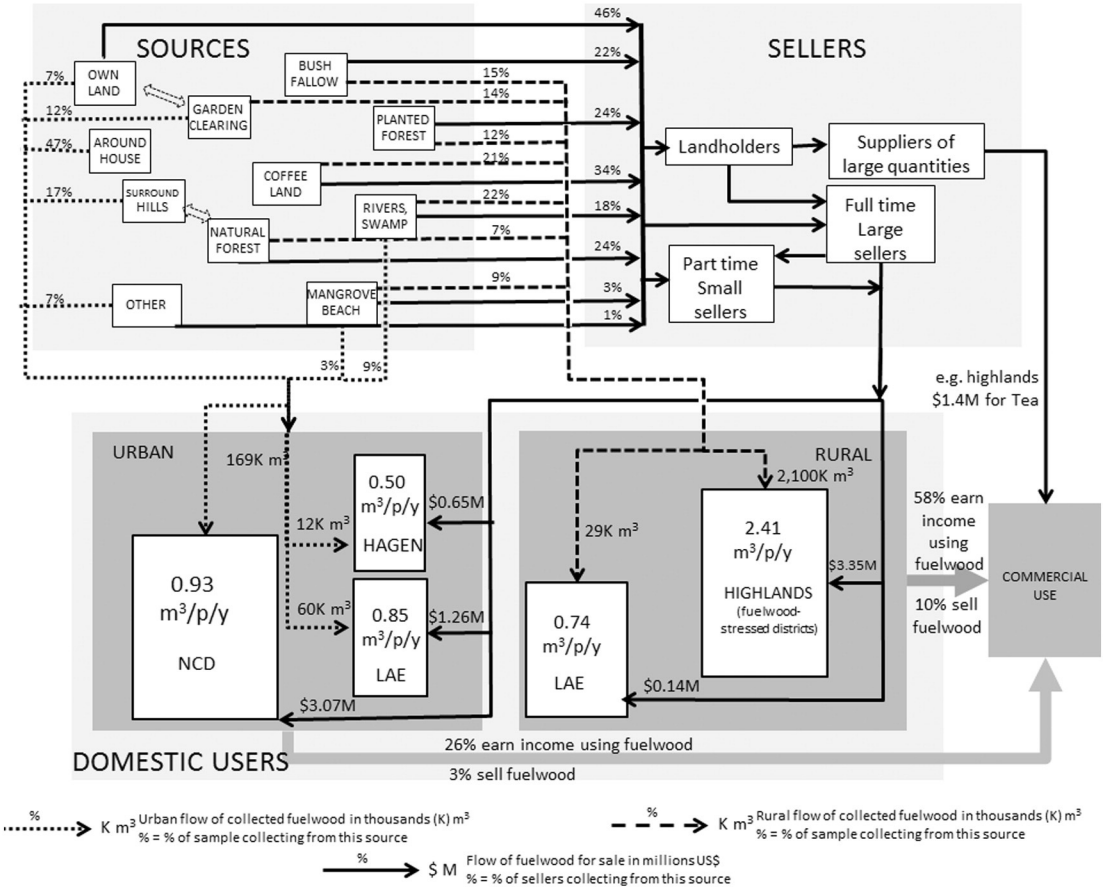

Fig. 2. Fuelwood flows, volumes and value in fuelwood stressed districts of PNG.

Fuelwood use is unsophisticated and inefficient

The most common form of fireplace is a simple open fire outside the house (51%) or similarly open fire inside the house (34%), the preferences for these arrangements much higher in rural areas (69% and 68% respectively). Many respondents had more than one type of arrangement associated with their dwelling. The use of drum ovens outside (32%) and inside (34%) also figures highly. Even slightly more sophisticated arrangements, such as metal boxes or barbeques, were not common. The types of fuel-saving stoves being promoted in Africa and other developing regions (GACG, 2013; Manibog, 1984); East Africa (Clough, 2012); India (Kishore and Ramana, 2002), (Venkataraman, Sagar, Habib, Lam, and Smith, 2010); China (Smith, Kennedy, Shah, and Schreier, 1993) were not observed at all either in domestic or small commercial operations.

The ceremonial and celebratory use of fuelwood is most commonly in the form of traditional *mu-mu*; where rocks are heated in a pit oven and the food (e.g. pig, sweet potato, yams etc) are cooked on the radiant heat once the fire is removed. Table 3 row 23 presents the estimated purchases of fuelwood for these purposes for the survey year. The survey could not detect how much fuelwood was freely gathered for this specific purpose.

Charcoal is considered an improved energy source because it generates much less smoke and it is lighter and cheaper to transport (Antal and Gronli, 2003). The charcoal market in PNG is very small and barely obvious. Charcoal imported from Australia is sold in urban centres at an average price of USD 4.70/kg primarily for use in barbeques. Small amounts are produced locally and sold USD 0.70/kg Lae for Asian consumers who are familiar with its use. It is not commonly used by Papua New Guinean nationals.

There was an effort in the mid-1970s and early 1980s to establish charcoal as a relatively clean and affordable energy source in the NCD (Gamser, 1980; Gamser and Harwood, 1982; Harris, 1979). Research into the most appropriate charcoal kilns produced the TPI kiln (Tropical Products Institute) and the simpler Tongan Drum kiln. Equally simple and cheap charcoal stoves were also developed (Nakau) and promoted (Kamila, 1998). These stoves were even distributed among public servants at cost to prime the charcoal economy. However, the attempt stalled because of lack of charcoal supply and poor extension (Gamser and Harwood, 1983).

The knowledge of using of charcoal for cooking is not widespread. During the survey it appeared that most highland respondents were not aware that charcoal is a commercial product. 'Sakol' to them was just the coals left in the fireplace from the previous night.

Many people use fuelwood as a livelihood strategy

Use of fuelwood for income generation is high among both urban and rural domestic respondents (Table 3 row 15). This included activities such as baking, hot food vending and smoking fish. The proportions of interviewees in the urban and rural domestic surveys earning some income from selling fuelwood were 3% and 10% respectively. Much of this business activity is part-time to meet occasional expenses such as school fees and medical expenses. Table 4 indicates the range and distribution of incomes of people either using fuelwood to generate income or selling fuelwood. Accordingly, the average annual incomes generated using fuelwood were USD1629/y in urban areas and USD720/y in rural areas. The proportion of respondents earning >K5000/y (USD 2325) were 14% in urban and 5% in rural areas. Hot food vendors were interviewed along the Highlands Highway from Markham Bridge (Morobe Province) to Walia Water fall (Enga Province). Estimated incomes ranged from USD32 to K418/week and daily fuelwood consumption ranging from 10 to 30 kg/day.

Lime burning is a major source of income for many villages along the Morobe coast with access to dead coral and sea shells. This lime is used in the consumption of *buai*, or betel nut, and is widely traded throughout PNG. Incomes among lime burning groups ranged from USD395–22,320/y. Estimated annual fuelwood use of these groups ranged from 1920 to 60,000 kg/y. The net (i.e. income after costs) efficiency of burning wood to make lime is USD1.38/kg for bamboo but only USD0.15/kg for mixed hardwood species. Access to fuelwood through collection or purchase did not seem to be a problem in this region; mangroves are observably protected from wood collection and reefs from live coral collection.

Table 5 presents the core results from the special survey of fuelwood vendors. 36% of vendors identified fuelwood sales as their sole source of income. 92% of vendors earned K5000 or less in the previous 12 months. (The official minimum wage for PNG is K5240.) So, only 8% of vendors earned >K5000. The maximum income was recorded as K70,000 of a large vendor (family group) in Mt Hagen.

Perhaps the most important finding in Table 5 is the range of values for fuelwood per kilogramme. The high prices in Mt Hagen reflect the dependence on and scarcity of fuelwood in the WHP. Throughout PNG fuelwood is sold in bundles at standard prices: PGK 2, 5, 10 etc. The lower value/kg in NCD reflects larger bundles for a given price point, presumably for quicker sales.

Fuelwood economy is largely informal

The RWEDP surveys mentioned in the introduction identified three parallel sectors in the fuelwood economies of the 16 Asian countries surveyed: 1] A formal sector supplied by the government forest organisation subject to regulation. The wood is sold either directly to the public or through wholesalers and retailers; 2] An informal sector of suppliers operating outside of the formal regulations who directly gather and sell locally, or sell to truck drivers transporting the fuelwood to a distant market. This sector also includes that fuelwood that is directly gathered by the consumer; 3] A private sector where the agents will buy the wood as whole trees, engage in the processing and transport of product to distant wholesale and retail markets. The private sector is generally thought to have the largest impact on overall fuelwood supply (RWEDP, 1996).

In PNG there in no formal sector in the fuelwood market. The PNG Forest Authority does not have an explicit fuelwood policy, nor does it have the capacity to undertake specific fuelwood plantings. There are no regulations on the harvest, transport or trade of fuelwood as there are in all the RWEDP countries. The only regulations affecting fuelwood are those imposed by local government or landlords who forbid the use of fuelwood within certain precincts. In the NCD, 25% of interviewees could not use fuelwood at home for this reason; the value was 9% in both the Lae and Mt Hagen urban samples.

The informal sector predominates with most fuelwood being gathered directly by users. Of the fuelwood vendors interviewed 84% were classed as informal, and this was following a sampling procedure that was likely to preference larger vendors who operate on a permanent basis. In addition, 3% of urban and 10% of rural interviewees in the domestic user surveys indicated that they sold fuelwood on a part-time basis; they will all fall into the informal sector. These proportions scale up to indicate that there were about 13,000 urban and 32,000 highland rural people were involved in the informal sector in the survey year. About 35% of the interviewed vendors fell into the USD1-2000/y category, while the rest earned below this.

A numerically small but highly visible private sector also exists. These enterprises are in two forms: selling retail fuelwood from a permanent site; or trucks which pick up fuelwood from roadside suppliers and deliver to large customers (e.g. factories, hospitals, schools, barracks etc). The partnerships and purchasing patterns of the sedentary enterprises are characteristically kept within extended family and clan boundaries, and the level of investment may include a chainsaw and/or a truck. The truck-delivery enterprises will purchase fuelwood wherever it is on offer. Indeed, 17% of the informal vendors sell to the

truck traders. These two types of private enterprise are relatively lucrative with an income range from USD 23–44,000/y.

Conflict over collected fuelwood is serious

Access to fuelwood had become more difficult for 65% of urban and 41% of rural respondents over the 2 year period previous to the survey (Table 3 row 7 for district values). Problems with accessing fuelwood are particularly severe in the coastal wards of NCD such as Napa Napa (84%) and Kila Kila (82%); populations closest to the mangroves around Port Moresby. A decade earlier the problem was nowhere near severe, but one can safely assume a trend of increasing conflict over access to fuelwood into the future.

The experience of conflict related to fuelwood collection is very high across all survey districts; this is particularly so considering the proportion of users who buy their fuelwood in urban areas. It is relatively low around Lae because the hinterland is well-treed. (Lae's average annual rainfall is 4636 mm compared with Port Moresby's 1012 mm). Conflict over fuelwood in the highlands is very common because: everyone uses but very few people purchase fuelwood; the population density is very high (e.g. 3 highland provinces 38–59 persons/km^2 cf Morobe and national average of 15 person/km^2); the region is culturally very diverse (there are 42 traditional languages over the three highland provinces in the survey); and inter-tribal conflict is common over all aspects of rural life, not just fuelwood collection (Reilly, 2008). The nature of the conflict reported ranged from quarrels and demands for compensation to serious fights leading to injury and death. An associated problem is the real threat of harassment and rape of women while in the process of collecting fuelwood.

As a consequence there was strong agreement (62–95%) with the need to plant more fuelwood trees Table 3 row 9), but this was by no means universal for reasons ranging from lack of good sites (e.g. around NCD) to abundant natural supply (e.g. around Lae).

A strong tree-planting culture

Trees feature prominently in the traditional farming systems of PNG. The high proportions of interviewees who plant trees (Table 3 line 12) indicate a strong culture of tree planting. This is an important consideration if smallholders are to be encouraged to plant trees specifically for fuelwood production. From the re-called data offered it is estimated that about 3.6 million trees were planted by the population in the survey regions in the 2 years previous to the survey. It is likely that most of the trees planted by urban respondents were not actually planted within the survey region, but on family land in rural areas.

Across the highlands Yar (*C. oligodon*) is by far the most preferred species for fuelwood (>85%). It is commonly planted in highland villages and a dominant shade species in coffee agroforestry systems (Bourke, 1985). In Mt Hagen there is also a preference for the introduced eucalypts (87%, mainly *Eucalyptus grandis* and *Eucalyptus robusta*), while in Henganofi and Chuave the indigenous PNG Oak (*Castonopsis acuminatissima*) is highly favoured (85 and 91%). Naturalised *Leucaena spp* is also an important fuelwood used in these areas (22 and 29% respectively).

Most of the vendors interviewed (78%) had access to land to grow trees for fuelwood with many of the NCD vendors have family land either in the NCD hinterland or Central Province (Table 3 row 13). Similarly most highland fuelwood vendors are selling close to their home village. The low values for Lae indicate that these vendors originate from areas other than Lae.

Impact of fuelwood gathering on forests is local not general

In PNG there was common perception before the survey that fuelwood collection is a cause of deforestation. This is probably influenced by the 'fuelwood gap' theory that was current in the 1970s (Eckholm, 1975). This cannot be directly supported from the survey, and it is probably too simplistic a claim to make. The relationship between fuelwood collection, per se, and deforestation may be very location specific and not a general problem. This has been found to be the case in other developing countries where most fuelwood is collected from sources other than natural forests (Arnold and Persson, 2003).

In PNG urban areas 66% of non-traded fuelwood is collected from the sources such as: around the house, own land, garden clearings. The sources and proportion of respondents accessing these and other sources in both urban and rural populations are illustrated in Fig. 2. The proportion of fuelwood collected from mangroves around NCD was only 3% but this is having a significant impact and is of concern. Assuming these residents collected all their wood from this source, this could amount to about 6860 m^3/y around those population centres collectively. This may only be a localised problem as the lime burning communities on the Salamaua Coast south of Lae in Morobe Province were observed to respect the local restrictions and do not use mangrove wood for their business activity.

Rural residents can gather fuelwood more widely over the range of sources available. However it is possible that the 12% from garden clearings and 9% from natural forests could be impacting on forest integrity. The garden clearings have evolved from the traditional swidden cycle which left the land to recover for decades before re-clearing. With population growth the recovery periods have grown much shorter as a response to land pressure. The survey did not determine whether the garden clearings were new from natural forests, or from bush fallows, grassland or just garden fallows. So it is difficult to assess their direct impact on standing forest. However, it is estimated that 56% of land used for cultivation across all PNG is covered in secondary forest before it is cleared for planting (Allen et al., 2001).

It is likely that much of the wood collected from garden clearings and even under the 'natural forest' category was re-growth and could have been included under 'bush fallows'. Bush fallows are essentially a long-cycle agroforestry system and should not be considered as forest degradation. Nevertheless, the fuelwood collected from 'garden clearings' is equivalent to 43,708 m^3/y. The 9% collected from 'natural forests' is equivalent to 8552 m^3/y in the fuelwood-stressed districts. Is this a significant and unsustainable harvest? This is difficult to answer and won't be attempted here. The only comparison available is the total raw log export volume for PNG in 2006 which was about 2.7 million m^3 (Shearman et al., 2008).

A survey of PNG forests using remote sensing imagery showed that over the period 1972–2002 15% of PNG's rainforest was cleared and 9% degraded to secondary forest. The expansion of subsistence agriculture contributed to 46% of the net forest change over this period. A further 4.4% of forest was lost due to fire associated with subsistence agriculture (Shearman et al., 2008).

The PNG population grew from 2.7 to 5.6 million in this period and the highest population densities exist in highlands between 1200 and 2500 m. There is a strong relationship between population density and forest loss in lowland and island regions, and this relationship is also apparent in the highlands. About 30–40% of the population lives in the highlands, growing at 3.2%/y and showing no signs of slowing. The average population density is 22 persons/km^2 with patches of 200 person/km^2 (Allen et al., 2001). The next densely populated region is the islands (10 person/km^2).

Given the high population in the highlands one could be struck by how relatively little deforestation and degradation of rainforests has occurred in the highland provinces. Earlier studies analysing forest change between 1975 and 1996 claimed that population increase in the highlands was accommodated by intensification of garden systems rather than clearing for more gardens (McAlpine et al., 2001). The Shearman et al. (2008) study, which is over a longer time span and finer resolution, disputes this and squarely points the finger at garden clearing being the main cause of deforestation. Filer et al. (2009) contest this claim with the view that much of what is called deforestation is actually part of

the traditional cycle of farming, fallow and regrowth; i.e. what is called "bush fallow" in the current paper.

None of these studies adequately quantify the relationship between clearing for gardens, tree planting in gardens, collecting fuelwood, fires caused by clearing and the processes of regeneration. Elsewhere in the world (eg Nepal: (Bajracharya, 1983)) deforestation is understood to be primarily a response to clear forest for food cultivation, not so much for fuelwood. So it is the food-fuel system that needs to be understood, particularly in a region like the Waghi Valley in WHP.

Overview of the fuelwood economy

In a broad view, the fuelwood economy in PNG, compared to other developing countries where similar studies have been done, has a relatively flat structure with a very short and direct supply chain. Fuelwood is regularly used by most of the population for domestic and commercial cooking, even in urban areas where there is good access to electricity and other energy sources. In the domestic market, most fuelwood vendors are collectors although larger vendors may buy from landholders and sell on to smaller vendors as well as selling directly themselves. In the industrial market it is largely supplied by local traders who pick up wood from roadside collection points. Selling fuelwood is an easy market to enter with many people entering it on a part-time basis. It is an informal economy in that there is no public engagement in supply, marketing, distribution, pricing, taxation, and use (except for instances of the prohibition of firewood use in some urban areas). Tree planting is widely practiced and many of these trees would be used for fuelwood. Value-adding of fuelwood into charcoal exists but it is on a very small scale, fragmented and infrequent.

Fuelwood consumption is estimated to be 1.8 m^3/person/year which is 6 times greater than the average consumption of 16 south and south-east Asian countries in the FAO Regional Wood Energy Development Program (and only exceeded by Bhutan). The absence of fuel-efficient stoves must surely contribute to this high value. In PNG there will be at most (and rarely) 2 intermediaries between landholder and fuelwood consumer; this compares with other countries which can have up to 7–8 intermediaries (Hadikusumah et al., 1991; Cruz et al., 1991; Hyman, 1983). PNG also contrasts with these countries in the absences of government involvement in either trade or regulation of the fuelwood market, a significant organised private sector, and a charcoal market.

Fig. 2 illustrates the flow of wood from various sources to urban and rural users through free collection and the market. The percentage values on the flow lines indicate the proportion of collectors who access their wood from these sources. While it would be useful to be able to quantify the volume of fuelwood from each of these sources, the data from this survey can't make that estimate. However, estimates are made of the volume of fuelwood that flowed into each of the districts the year of the survey using Eq. (2).

General discussion and conclusion

Fuelwood surveys reveal the dimensions and significance of fuelwood in the domestic economy and its regional variations. As such they can better inform public policy and private business decisions that can have wide-reaching impacts on industrial and small-business development, public health, and forest management.

In summary the survey shows the following: most people continue to use fuelwood even in the presence of other energy sources; its use in the home and market place is unsophisticated and inefficient because there has been scant interest in improving it; many people use fuelwood as a livelihood strategy, with some earning good incomes; conflict over fuelwood collection is serious and growing; there is a strong tree planting culture; and the environmental impact of fuelwood collection is local but not general; the economy is largely informal.

This survey shows that firewood will remain a key component of PNG's domestic energy economy for long into the foreseeable future, especially in rural areas. The way this fuelwood is accessed must change in response to population growth and increasing intensification of land use. Its socio-economic value needs to be formally recognised and integrated into the domestic energy economy along with modern, imported fuels.

The first step for this would be a National Fuelwood Policy. Clearly, this policy would not be just a forestry issue, but embraces the sectors of: energy, agriculture, education, community development and regional economic development. Without pre-empting this policy, it seems that the government intervention should not be of the sort to tax or regulate the flow of this trade, as people will easily find ways around these regulations. However, the Government of PNG could create conditions to encourage the organised private sector to invest in fuelwood trade and create economies of scale. The Government's regulatory role would then be to ensure that this firewood is sustainably harvested or grown, and that actors in the informal market are still protected. Local and provincial governments could encourage the use of clean burning charcoal in public places (some local jurisdictions, eg Goroka, already prohibit firewood in the market place).

Such a policy would need further research to inform its development. Modelling of local woodflows in communities would help understand the role of regeneration of wood harvest from village gardens, bush fallows, natural forests, plantations, public areas. Such models would help pinpoint areas where fuelwood gathering is, or will be, causing deforestation and areas where fuelwood collection is buffered by natural regeneration.

Consumers' choice about energy sources is very complicated and likely to concern much more than relative prices. Both econometric and social studies of the domestic energy market could explain the very large difference price (per kg) of fuelwood around the country, as well as help design market instruments to encourage the organised private sector to invest in the fuelwood market.

Acknowledgements

This study was sponsored by the Australian Centre for International Agricultural Research as part of the project Promoting Diverse Fuelwood Production Systems in PNG Project FST/2006/088 (Nuberg, 2013a). The author is very grateful to the following people: from Foundation for People and Community Development who implemented the questionnaire survey and case-study monitoring activity Yati Bun (director), Israel Bewang (coordinator), Bazakie Baput, Bonti Krasi, Fletcher Onise, Kafuri Yaro, and Linzon Zamang; from the PNG Forest Research Institute, Lae, who undertook the semi-structured interviews John Paul, Agnes Sumareke and Maman Tavune; and Dessy Kusbandi for data entry.

References

Allen B, Bourke R. & Hanson L. Dimensions of PNG village agriculture. In: Bourke R, Allen M, & Salisbury J, Eds., Food Security for Papua New Guinea. PNG University of Technology, Lae: Australian Centre for International Agricultural Research; 2001. pp. 529-553.

Anon. Special issue: gender and wood energy. Wood Energy News, 2; 1995 [20 pp.-20 pp.].

Antal MJ, Gronli M. The art, science, and technology of charcoal production. Ind Eng Chem Res 2003;42(8):1619–40.

Arnold M, Persson R. Reassessing the fuelwood situation in developing countries. Int For Rev 2003;5(4):379–83. http://dx.doi.org/10.1505/ifor.5.4.379.22660.

Bank of PNG. Bank of Papua New Guinea QEB statistical tables; 2014 [Retrieved 21/05/2014, from] http://www.bankpng.gov.pg/.

Bajracharya D. Fuel, food or forest? Dilemmas in a Nepali village. World Dev 1983;11(12):1057–74.

Bourke R. Food, coffee and casuarina: an agroforestry system from the Papua New Guinea highlands. Agrofor Syst 1985;2(4):273–9.

Bourke R. Management of fallow species composition with tree planting in PNG. In: Casson A, editor. Resource management in Asia-Pacific. Canberra: Division of Pacific and Asian History, Research School for Pacific and Asian Studies, Australian National University; 1997.

Brown C, Asia pacific forestry sector outlook study: regional study—The South Pacific Working Paper Series. Regional Office for Asia and the Pacific, Bangkok: FAO; 1997.
Cardoso MB, Ladio AH, Lozada M. The use of firewood in a Mapuche community in a semi-arid region of Patagonia, Argentina. Biomass Bioenergy 2012;46:155–64. http://dx.doi.org/10.1016/j.biombioe.2012.09.008.
Clough L. The improved cookstove sector in East Africa: experience from the Developing Energy Enterprise Programme (DEEP). [Retrieved from] www.gvepinternational.org, 2012.
Cruz F, Ortega-Espaldon V, Duma J. Rural–urban dependence on wood energy in a selected area in Laguna Province, Philippines. A Rapid Rural Appraisal. Wood fuel flows, field document 26, part III. FAO, RWEDP; 1991.
Eckholm E. The other energy crisis: firewood. Washington: Worldwatch Institute; 1975.
FAO. Forest resources assessment 1990: tropical countries. Rome: Food and Agriculture Organization of the United Nations; 1993.
FAO. Regional study on wood energy today and tomorrow in Asia. In R. W. E. D. l. P. i. Asia (Ed.), GCP/RAS/154/NET. Bangkok: Food and Agriculture Organisation; 1997. pp. 168.
FAO. Global forest resources estimates 2010. Papua New Guinea country report. FRA2010/161; 2010. [from http://www.fao.org/forestry/fra/en].
FAO-RWEDP. Regional wood energy development programme in Asia. [Retrieved 21/03/2014, from] http://wgbis.ces.iisc.ernet.in/energy/HC270799/RWEDP/index.html, 1999.
Filer C, Keenan RJ, Allen BJ, McAlpine JR. Deforestation and forest degradation in Papua New Guinea. Ann For Sci 2009;66(8):813.
GACG. Global alliance for clean cookstoves. [From] http://www.cleancookstoves.org/, 2013.
Gamser M. Household energy consumption in Port Moresby. Report no. 8/80. Port Moresby, Papua New Guinea: Energy Planning Unit, Department of Minerals and Energy; 1980.
Gamser M, Harwood C. Charcoal production and use in Papua New Guinea. Konedobu, PNG: Energy Planning Unit, Department of Minerals and Energy; 1982. p. 44.
Gamser M, Harwood C. The implementation of new energy technologies in developing nations: problems and policies in the introduction of charcoal in Papua New Guinea. GeoJournal 1983;7(1):35–40.
Hadikusumah H, Karyono, Parikesit, Rusydi. Rural–urban interdependencies in the commercial wood energy systems in Majalaya sub-district, West Java. In: RWEDP F, editor. Wood fuel flows, field document 26 part IV; 1991.
Hanson L, Allen B, Bourke R. Papua New Guinea rural development handbook. Canberra: Australian National University; 2001.
Harris A. Charcoal production in Papua New Guinea: an assessment of selected sites, technologies and feedstocks. Port Moresby, PNG: D. M. a. E. a. D. L. a. Industry, Trans; 1979. p. 32.
Hyman EL. Analysis of the woodfuels market: a survey of fuelwood sellers and charcoal makers in the province of Ilocos Norte, Philippines. Biomass 1983;3(3):167–79.
Kamila VB. Charcoal and charcoal stove making. Lae, PNG: Appropriate Technology and Community Development Institute. Papua New Guinea University of Technology; 1998.
Kishore V, Ramana P. Improved cookstoves in rural India: how improved are they? A critique of the perceived benefits from the National Programme on Improved Chulhas (NPIC). Energy 2002;27:47–62.
Larinde SL, Olasupo OO. Socio-economic importance of fuelwood production in Gambari forest reserve area, Oyo State, Nigeria. J Agric Soc Res 2011;11(1):201–10.
Manibog F. Improved cooking stoves in developing countries: problems and opportunities. Annu Rev Energy 1984;9:199–227.
McAlpine J, Freyne D, Kei G. Land use and rural population change in PG, 1975–96. In: Bourke R, Allen B, Salisbury J, editors. Food security for Papua New Guinea. Monograph No. 99ACT, Australia: ACIAR; 2001.
Murphy, M. (2006). What is free about fuelwood?: a critique. (unpublished PhD thesis), Southern Cross University, Lismore, New South Wales.
Nakau C. (n.d.). ATCDI Program Activities. PNG University of Technology, Lae: Appropriate Technology and Community Development Institute.
Nizami A. Forest fights in Haripur, Northwest Pakistan; 2013.
NSO. Community profile system of the PNG national census. Port Moresby: National Statistics Office, PNG Government; 2000.
Nuberg I. Survey of fuelwood-stressed regions of Papua New Guinea (Vol. Appendix 1, pp. 164). ACT: Australian Centre for International Agricultural Research; 2013a [available from http://aciar.gov.au/publication/fr2013-14].
Nuberg I. Promoting diverse fuelwood production systems in Papua New Guinea. Canberra: Australian Centre for International Agricultural Research; 2013b. p. 108 [Publication code FR2013-14, available from http://aciar.gov.au/publication/fr2013-14].
Raghupathi D, Venkaiah K. Fuelwood collection pattern of head loaders in HD Kote Taluk area of Rajiv Gandhi National Park, Karnataka. Environ Ecol 2007;25S(Special 1):39–42.
Reilly B. Ethnic conflict in Papua New Guinea. Asia Pacific Viewpoint 2008;49(1):12–22.
RWEDP. Woodfuel Flows. In R. W. E. D. Project (Ed.). Bangkok: Regional Wood Energy Development Project; 1996. pp. 43.
Shearman P, Ash J, Mackey B, Lokes B. The State of the Forests of Papua New Guinea. Mapping the extent and condition of forest cover and measuring the drivers of forest change in the period 1972–2002. University of Papua New Guinea; 2008.
Smith K, Kennedy G, Shah P, Schreier H. A district evaluation of fuelwood resources in Nepal. For Chron 1993;69(5):594–9.
USDS. Country reports on human rights practices for 2013. [Retrieved 21/05/2014, from] http://www.state.gov/j/drl/rls/hrrpt/humanrightsreport, 2013.
Vegter A. Forsaking the forest for the trees: forestry law in Papua New Guinea inhibits indigenous customary ownership. Pac Rim Law Policy 2005;14(2):30.
Venkataraman C, Sagar A, Habib G, Lam N, Smith K. The Indian National Initiative for Advanced Biomass Cookstoves: the benefits of clean combustion. Energy Sustain Dev 2010;14:63–72.