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Patterns and Determinants of Domestic Energy Use in Kanchenjunga Himalaya

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Abstract: In the Kanchenjunga Transboundary Conservation Landscape of the Eastern Himalaya, people remain dependent upon biomass energy for virtually all domestic uses, including cooking food, boiling water and tea, space heating, and preparing cattle feed. Liquefied Petroleum Gas (LPG) is being adopted only gradually and unevenly. We examined patterns and determinants of fuel wood versus LPG use for 250 households in India and Nepal. Over 90% of households use fuel wood for the purposes mentioned above. Major determinants of fuel wood consumption rates include household (family) size, education level of household head, number of cattle owned, and time spent collecting fuel wood. Major determinants of LPG use include age and education level of household head, household size, household income, time spent collecting fuel wood, membership of the household head in social organization, and land tenure status. Patterns of fuel wood use differ across Indian and Nepali sites. These differences are correlated with differences in the social, economic and policy factors mentioned above. Our results suggest that direct promotion of LPG may not contribute greatly to reductions of fuel wood use and the consequent pressure on forest resources. On the other hand, investment in a number of social and economic factors, including education and improved ownership of forests by local communities, can in some cases reduce fuel wood use, consequently ameliorating forest degradation caused by overharvest of fuel wood.

Keywords: Fuel Wood, Biomass, LPG, Energy, Forests

1. Introduction

Fuel wood and other biomass gathered from forests remain the major source of household energy worldwide. This is especially true in the rural areas where most economically deprived people live [1-3], though charcoal is increasingly common in cities. Globally, more than 2 billion people rely on biomass energy for cooking and heating [4-5], and biomass contributes to approximately 10 percent of the global energy supply, with a two-thirds being used in developing countries [6]. This accounts for about half of the global wood harvest [7-8]. Projections indicate that consumption of fuel wood will rise continuously over the near future in developing countries except East Asia and South-East Asia; while demand for charcoal in cities is expected to grow there as well [9-11].

Consumption of fuel wood, both commercial and domestic, has been described as one of the main drivers of forest degradation throughout the world [5, 12, 13, 14], though there are many local variations. For instance, in northeastern India, one study estimated that fuel wood harvest accounts for 50% of the conversion of forestland to wastelands [15]. Similarly, two decades ago, over 80% of the deforestation in the Philippines was attributed to fuel wood extraction [16]. The contribution of fuel wood extraction to deforestation rates has also been discussed for developing countries including Pakistan and Nepal [17-18]. Deforestation and forest degradation leading to loss of forest productivity has been thought likely to produce local fuel wood crises [19], with environmental and social implications such as increasing time spent on wood collection and greater reliance on low-energy agricultural residues as fuel [5, 20].

The history of warnings of fuel wood crisis has, however, been criticized for oversimplification [21-22], and it appears that relationships between fuel demand and supply are complex and variable across sites. Nevertheless, fuel wood burning has clear negative consequences for carbon budgets, emissions of greenhouse gases and particulate matter, ecosystem health, human health, and livelihoods [23-26].

Large-scale plantations have been suggested as potential solutions to the challenges posed by overconsumption of fuel wood [19]. Fuel wood consumption can also be economized by applying efficient burning techniques such as Improved Cooking Stoves; or by replacing wood with alternative biofuels such as crop residues or animal dung, which have their own negative consequences [2-3]; or by switching to advanced energy technologies [27]. Several energy-saving and relatively environmentally friendly alternative energy technologies (solar, wind, bio-briquette, hydroelectricity, biogas, kerosene, Liquefied Petroleum Gas [LPG]) are already available for reducing fuel wood consumption and mitigating carbon emissions [28]. A few organizations have been promoting biomass gasification as a viable alternative technology for parts of India [29]. Unfortunately, adoption of such energy technologies is very slow, especially in rural areas [14]. Large-scale adoption is particularly challenging in the hills, where alternative energy technologies are mostly unavailable, inaccessible due to limited transportation infrastructure, or unaffordable. In addition, people often prefer fuel wood because it is a “free” good, whereas alternative energy technologies involve cost and/or are often accompanied by difficult-to-operate devices [30].

To reduce fuel wood consumption and promote alternative energy in order to curb deforestation, it is important to examine patterns and processes of fuel wood use, and to understand the factors influencing people’s decisions regarding fuel wood consumption and the adoption of alternative energy technologies. Previous studies point to a range of socio-cultural, demographic and economic factors influencing the decisions on fuel wood use [31]. Family size, household income, livestock number, ethnic group, stove type, labor availability, and access to forestlands are all held responsible for fuel wood consumption rates [14, 15, 32, 33].

Throughout the Himalaya, information is lacking about the factors motivating people to adopt LPG in order to develop LPG promotion policies. Promotion of alternative energy is of utmost importance in the region, since most forests are in designated protected areas. Tourism is also increasing rapidly in many areas, adding to the pressures on forest resources. Thus, location- and context-specific studies are needed to devise appropriate policies. Studies in the Sikkim Himalaya have reported on peoples’ preferences for certain tree species on the basis of energy value, biomass-ash ratio, and forest density [18-34], but these and other local studies are limited in scope.

Research in the Kanchenjunga Landscape of the Eastern Himalaya departs from previous studies in three respects. First, we examine a range of determinants of household resource use across a biodiversity-rich region of major global significance. Second, we analyze economic policies underlying the use of alternative fuels. Third, by working in a transboundary area, we compare potential influence of two governance regimes on patterns of fuel wood use of comparable communities to gain further insight to how policies may shape the use of fuel wood and LPG. We address the following questions: (a) What are the patterns and processes of fuel wood consumption and LPG adoption across rural Eastern Himalaya? (b) What factors are responsible for variation in these patterns, including across the India-Nepal border? (c) What sociocultural impacts does fuel wood use have in the local villages?

2. Study Sites and Research Design

2.1. Research Sites

The study was conducted in selected villages of the Kanchenjunga Transboundary Conservation Landscape, covering parts of three districts of eastern Nepal (Taplejung, Panchthar and Ilam), Darjeeling district and Assam and Sikkim states of India, and Samtse state of Bhutan [35-38]. Situated between 87.5^0 to 90.5^0 E and 26.5^0 to 28.1^0 N, the conservation landscape spreads over 14,432 km^2 and incorporates 14 protected areas (one each in Nepal and Bhutan and 12 in India), covering 6,032 km^2 [39]. The region is dominated by precipitous hills, snow-capped mountains and deep valleys, supporting a wide range of climatic and biological diversity. The climate ranges from humid sub-tropical in the lower belts to cold alpine with perpetual snow in the high mountains. Besides overall biological richness, the landscape also harbors several endemic, rare and highly threatened species [37, 40]. People of various ethnic groups, languages, religions and culture have lived in the region for generations. Many people on opposite sides of the India-Nepal border share common languages, culture, and patterns of reliance on environmental services. Indeed, many families have members living on both sides of the border.

Table 1. *Study sites and sample size.*

Survey sites	Name of villages	# of HHs surveyed
Samalbung, Nepal (~1500masl)	Samalbung-1	5
	Samalbung-4	61
	Site total	66
Okaity, India (~1500masl)	Sirubari	4
	Bhotey gaon	7
	Godam dhura	11
	9 number	25

Survey sites	Name of villages	# of HHs surveyed
	Beech gaon	14
	Site total	61
	Jaubari	32
	Jogmai-3	4
	Tumling	9
Jaubari, Nepal (~2100masl)	Guranse	5
	Gairibas	2
	Megma	11
	Site total	63
	Rimbik	11
	Danda gaon	11
Rimbik, India (~2100masl)	Sirikhola	8
	Namla gaon	8
	Mane danda	22
	Site total	60
Grand total		250

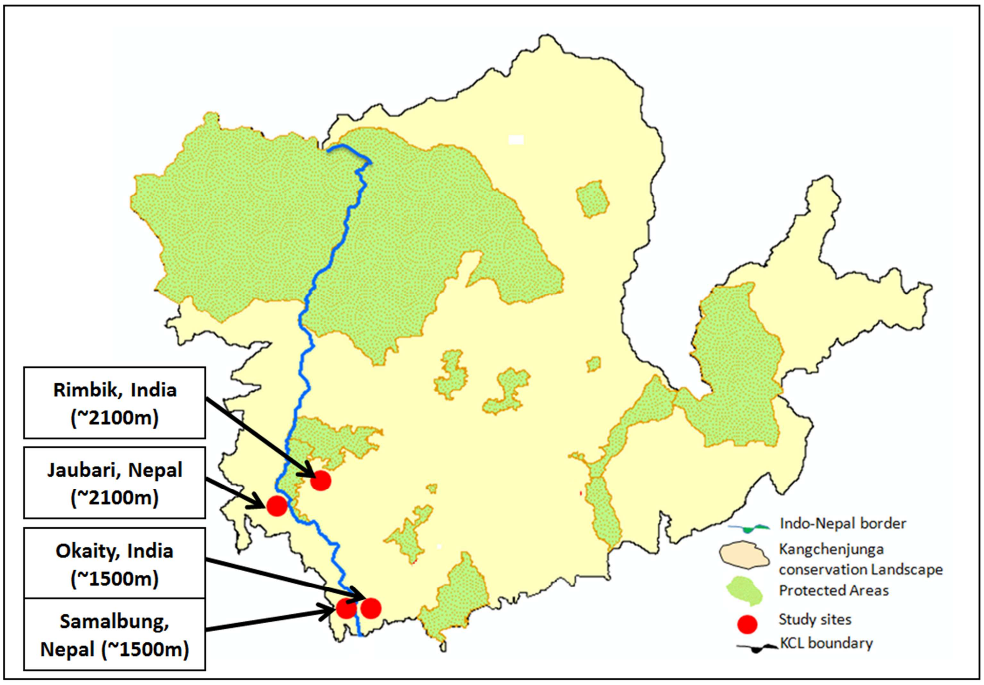

Figure 1. *Study sites shown in Kanchenjunga Transboundary Conservation Landscape.*

Table 2. *Basic characteristics of the research sites (averages, by site*).*

Site	Family size	Education level, HHH*	Age of HHH	Annual income (IRs)
Okaity (~1500masl)	5.08 (2.11)*	6.95 (4.02)	47.79 (15.29)	25,400
Samalbung (~1500masl)	5.18 (2.06)	3.71 (3.44)	53.15 (13.14)	20,400
Rimbik (~2100masl)	6.32 (2.37)	5.52 (3.55)	48.38 (14.62)	32,000
Jaubari (~2100masl)	4.71 (2.05)	4.84 (4.24)	45.30 (13.70)	30,900
Overall	5.31 (2.11)	5.22 (3.98)	48.72 (14.40)	27,000

Table 2. *Continue.*

Site	# cattle owned	Fuel wood consumed (*bhari**/ year)	Time spent collecting fuel wood (min/ day)	% of HH* possessing LPG
Okaity (~1500masl)	0.33 (0.56)	53 (38.08)	51 (54.63)	54%
Samalbung (~1500masl)	1.42 (1.38)	76 (61.24)	9 (11.44)	13.6%
Rimbik (~2100masl)	2.93 (1.93)	44.4 (30.60)	84 (50.13)	30%
Jaubari (~2100masl)	4.27 (4.34)	89.6 (23.56)	135 (57.79)	49%
Overall	2.24 (2.89)	66.21 (12.53)	71.71 (66.60)	34%

*Numbers in parentheses are standard deviation
*HH = Household
*HHH = Head of Household
**bhari* = Backload (approx. 40kg)

2.2. Sampling Techniques

We sampled four research sites within the Kanchenjunga Conservation Area: two each in Nepal and India. In each country, we selected one relatively low-elevation site (~1500masl) and one higher-altitude site (~2100masl). The four regions were Samalbung (Nepal) and Okaity (India) at lower altitudes, and Jaubari (Nepal) and Rimbik (India) at higher altitudes. Basic characteristics of the sites are given in Tables 1 and 2. From the four sites, we selected a total of 18 villages using well-defined criteria such as access, ethnic similarity, land use pattern, and community participation. A sample was then drawn from each village using random sampling (lottery method). Sample sizes ranged from 60-66 households in each site, yielding a total of 250 study households.

2.3. Data Collection Strategy

We conducted household surveys using semi-structured questionnaires to collect information regarding the amount of fuel wood used by the selected households for different purposes during summer, monsoon and winter. Although Fox [33] has suggested annual recall method as the most relevant way to recall fuel wood use, we used ‘weekly recall’ because for individuals living in the rural areas where record-keeping is poor, weekly recall may convey a more accurate picture than annual recall. In addition, information related to socio-economic factors was recorded to examine the role of those factors on firewood extraction

2.4. Data Analysis Techniques

We used descriptive analytic tools to calculate frequency of responses for different energy sources consumed for different purposes. The frequencies were then converted into percentages to ease comparison among sites. Quantities of fuel wood used in summer, monsoon and winter seasons were compared with one another using mean values, standard deviations and T-tests. People in the study sites reported that one *bhari* (backload) of fuel wood weighs about 40kg, so we took that as a basis for unit conversion. The analysis was done with the aid of PASW-18 for Windows.

2.5. The Models

Cause-and-effect relationships may be assessed either by computing the correlation between individual variables or by developing a model with the help of certain variables [41]. Choosing the explanatory variables to be included in an empirical model is often a difficult task [42-47]. We chose two different regression models: a multiple linear regression model to analyze factors determining the quantity of fuel wood consumption, and a multiple binary logistic regression model to analyze determinants of LPG use.

In the first model, the amount of fuel wood consumed was the dependent variable, while family size, number of cattle owned, education of household head, and time spent collecting fuel wood were chosen as independent variables (see the model below). Hypotheses for individual variables are shown in Table 3. We calculated Variance Inflation Factor (VIF) to make sure no multi-collinearity exists among variables included in the analysis. A VIF greater than 10 indicates multi-collinearity amongst test or independent variables, indicating that the data merits further investigation [48]. Since R^2 above 15% is considered acceptable in a model involving few independent variables [49-50], we report the results even though R^2 values for the model are low (16.6% for combined data and 10-27.2% for individual sites).

$$Y = ß_0 + ß_1 \text{ Family size} + ß_2 \text{ Number of cattle owned} - ß_3 \text{ Education} – ß_4 \text{ Time spent collecting fuel wood}$$

For the second model, possession of LPG was the dependent variable, while independent variables included family size, income, age, education, time spent collecting fuel wood, membership in social organizations, and access to environmental programming on television. The following model was used descriptions of variables used in the model are summarized in Table 3.

$$\text{Logit } [p] = ß_0 – ß_1 \text{ Household size} + ß_2 \text{ Income} - ß_3 \text{ Age} + ß_4 \text{ Education} + ß_5 \text{ Time to collect}$$

$$\text{fuel wood} + ß_6 \text{ Membership in social organizations} + ß_7 \text{ Access to television}$$

Table 3. *Definitions of explanatory and response variables.*

Variables	Explanation	H_o (FW)	H_o (LPG)
Dependent			
Amount of FW	Total amount of fuel wood consumed (*bhari*/week/HH)		
Possession of LPG	Household does (1) or does not (0) possess LPG		
Independent			
Family size	Total number of household members	+	-
Income	Gross annual household income	NA	+
Age	Age of household head	NA	-
Cattle	Number of cattle owned by household	+	NA
Education level	Total years of education of household head	-	+
Time collecting FW	Man-hours spent on round-trip travel for fuel wood collection	-	+
Membership	Is (1) or is not (0) a member of any social organization	NA	+
Television	Does (1) or does not (0) watch environmental programming on TV	NA	+

3. Results

3.1. Patterns and Processes of Fuel Wood Use

As Table 4 shows, virtually all households in the Kanchenjunga landscape continue to use firewood for most domestic uses. In Rimbik, a third of households also use LPG for cooking, while Okaity and Jaubari have the highest LPG adoption rate in our sample: about half use LPG for cooking at least occasionally. Okaity also has the lowest dependency on cattle. Nevertheless, all Okaity households continue to use fuel wood for most uses. In Samalbung, a smaller proportion of households use LPG for cooking food. Space heating with LPG remains very rare in this region. None of the households in these sites use LPG to prepare animal feed.

Table 4. *Fuel wood and LPG use rates for different purposes, by site.*

Site	Fuel wood use rates (% HHs)				LPG use rates (% HHs)			
	Cooking food	Heating living space	Boiling tea & water	Animal feed preparation	Cooking food	Heating living space	Boiling tea & water	Animal feed preparation
Okaity (~1500masl)	100	100	100	100	54	0	0	0
Samalbung (~1500masl)	100	100	100	100	14	1.5	9	0
Rimbik (~2100masl)	100	98	93	98	32	0	7	0
Jaubari (~2100masl)	90	89	81	100	49	3	36.5	0
Overall means	97.5	97	93.5	99.5	37	1	13	0

Averaging across all sites, a family consumes 5.16 *bhari* (back- or head-load) of firewood per week (equivalent to 3.95-5.26 kg/person/day at the rate of 40kg/*bhari*). A comparison of summer, monsoon and winter data showed that firewood is consumed at a significantly greater rate during the monsoon than during summer (1.5 times; t=-11.476, p<0.0001), and during winter than during the monsoon (1.2 times; t=-8.986, p<0.0001), as shown in Table 3 and Figure 2. Thus, nearly twice as much fuel wood is consumed during winter as during summer.

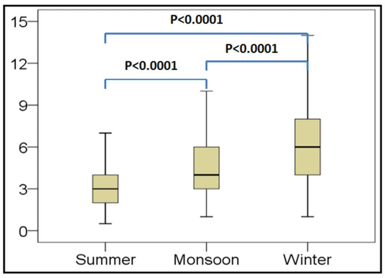

Figure 2. *Amount (backloads on average) of firewood used in different seasons.*

Table 5. *Amount (backloads on average) of firewood used in different seasons.*

Season	Average fuel wood per week (bhari/backload)	StDev
Summer	-2.296	3.037
Monsoon	.023	4.525
Winter	.142	4.188

3.2. Determinants of Fuel Wood Consumption

In our sample, the variables 'family size', 'education', and 'time spent collecting fuel wood' show negative associations with fuel wood consumption *per capita*, whereas the number of cattle owned by a family shows positive associations. Family size is negatively correlated with fuel wood consumption *per capita* across all four sites; whereas education is negatively correlated in Okaity only, and cattle is positively correlated in Okaity and Jaubari sites (Table 6). Equations for the overall study region and individual sites are presented below.

Table 6. *Determinants of household fuel wood consumption per capita in different sites.*

Variables	Coefficient and significance level				
	Overall	Okaity	Samalbung	Rimbik	Jaubari
Family size	-7.81***	-6.70**	-17.28***	-4.04**	-5.44**
Education	-1.67**	-2.54**	--	--	--
Cattle	1.92*	13.26***	--	--	3.93***
Time to collect firewood	-0.16***	--	--	--	--
Constant	113.58	100.10	167.83	70.50	58.90
R^2	0.181	0.272	0.263	0.100	0.256
Adjusted R^2	0.166	0.224	0.250	0.085	0.231

*significant at the 10% level; ** significant at the 5% level; and *** significant at the 1% level of significance

Overall $Y = \infty$ - *7.81 Family size – 1.67 Education + 1.92 Number of cattle owned – 0.16 Time to collect fuel wood*

Okaity: $Y = \infty$ - *6.70 Family size – 2.54 Education + 13.26 Number of cattle owned*

Samalbung: $Y = \infty$ - *17.28 Family size*

Rimbik $Y = \infty$ - *4.04 Family size*

Jaubari $Y = \infty$ - *5.44 Family size + 3.93 Number of cattle owned*

3.3. Factors Affecting Adoption of LPG

The single strongest determinant of LPG adoption in this landscape is undoubtedly road access, since heavy and bulky LPG canisters need to be delivered regularly to any household using an LPG stove. The majority of the villages in this study had adequate road access, so this should not be a factor in our analysis. Other possible correlatives of a household's decision whether to adopt LPG are age and education level of household head, land ownership, household income, time occupied in collecting fuel wood resources, membership in social organizations, and access to environmental programming on television. The equation for the model derived from the analysis is shown below and output is presented in Table 7.

Table 7. *Determinants of LPG adoption.*

Variables	B	S. E.	Wald	Sig.	EB
Constant	-2.296	.812	7.990	.005	.101
Age of HH head	.023	.012	3.742	.053	1.023
Education of HH head	.142	.044	10.221	.001	1.152
Family size	-.145	.076	3.575	.059	.865
Annual income	.001	.000	3.353	.067	1.001
Time spent collecting FW	.004	.002	3.028	.082	1.004
Membership in social orgs.	1.126	.554	4.136	.042	3.084
Environmental TV programs	.518	.299	2.993	.084	1.678

$$\text{Logit }[p] = -2.296 + 0.023\text{ Age} + 0.142\text{ Education} - 0.145\text{ Family size} + 0.001\text{ Income}$$

$$+\ 0.004\text{ Time spent collecting fuel wood} + 1.126\text{ Membership in social organizations} + 0.518\text{ Environmental TV programs}$$

3.4. Comparison of Determinants Between Nepal and India

A cross-border comparison shows that fuel wood consumption *per capita* is significantly higher in Nepal sample sites than those in India ($p<0.001$). Educational level of household heads and average annual income are both significantly higher in India than Nepal, indicating that these variables might be contributing to reductions in fuel wood consumption *per capita* (see Discussion section). However, membership in social organizations and watching environmental programming on television are significantly higher for the Nepali sample than the Indian ($0.01<p<0.05$), indicating either that these variables are not contributing substantially to reductions, or that the usage differential would be even greater if these habits were not prevalent in Nepal. It could also simply indicate that environmental programming is a more significant element in Nepali television than in Indian, but in any case it does not appear to be having a strong effect on people's behavior as regards fuel wood use. The social organizations to which farmers belong in Nepal are mostly government-sponsored groups established specifically to manage forest resources, and the fact that they do not seem to be helping manage fuel wood use rates may constitute a critique of their effectiveness, as they are relatively newly-formed groups. The number of cattle owned is positively associated with fuel wood consumption, doubtless because a good deal of wood is used in preparing cattle fodder. Time spent collecting fuel wood is higher in Nepal, but not significantly so (Table 8).

Table 8. *Comparison between Nepal and India in parameters related to deforestation.*

Variables	Test used	Nepal	India	Statistics (t or χ^2)	P-value
Fuel wood use per capita (*bhari*/week)	t	83 (±14.95)	49 (±3.15)	5.100	0.000***
Average family size (# of individuals)	t	4.95 (±0.182)	5.69 (±0.192)	2.803	0.005***
Educational level of HHH (last grade attended)	t	4.26 (±0.342)	6.24 (±0.350)	4.039	0.000***
Average annual income (US $)	t	345 (±29.899)	624 (±57.700)	0.918	0.395
Mean number of cattle per household	t	2.81 (±0.307)	1.62 (±0.175)	2.221	0.028**
Time spent collecting fuel wood	t	74 (±6.841)	70 (±5.251)	0.476	0.635
% of HHH with membership in social organizations	χ^2	14.72	1.65	13.874	0.000***
% of HHH watching environmental programming on television	χ^2	49.61	37.19	3.918	0.048**

Note: Figures shown in parentheses are standard errors; ¶T-test; §Chi-square (χ^2) test; **significant at the 5% level and ***significant at the 1% level

4. Discussion

4.1. Patterns and Magnitude of Fuel Wood Use

On average, a household in the Kanchenjunga Conservation Landscape consumes about 4–5 kg/capita/day on an annual basis. Studies from other parts of the Himalaya have shown a similarly high level of dependency on fuel wood [15, 18, 20] and a similar range of fuel wood consumption. Bhatt and Sachan [15], for instance, have estimated an average fuel wood consumption of 3.90-5.81 kg/capita/day for northeast Himalayas, while Maikhuri [51] and Shankar [52] give estimates of 3.1-10.4 kg/capita/day for Arunachal Pradesh. In the western Himalayas [53] and the Nepal Himalayas [54], researchers have found much lower consumption rates, namely 1.49kg/capita/day and 1.23 kg/capita/day fuel wood, respectively, for the two regions. It seems likely that these differences reflect the diminishing influence of the summer monsoon in the westerns sections of the range. More fuel wood is required during monsoon and winter, because in the East, the monsoon is mostly cloudy, wet and cool, while winter is foggy, misty and often extremely cold. The preferred species harvested for fuel in our study sites include *Quercus spp.*, *Alnus nepalensis, Castanopsis spp.,* and *Schima wallichii.* These are among the high-quality fuel woods identified by Chettri and Sharma [20].

These findings conform to results obtained in other parts of the Eastern Himalayas [5, 15, 55, 56]. Current scenarios of expected climate change may engender optimism as regards pressure on forests from fuel wood consumption. If average temperatures continue to increase as predicted by IPCC [57] and other studies [58-60], less fuel wood might be required. However, predicted regional increases in overall precipitation, and in the intensity of monsoons, cyclonic storms and protracted winter droughts, all imply an increase in periodic wind and water stresses. These could substantially constrain forest productivity, especially at the local scale. Unfortunately, our ability to forecast patterns of climate change at the scale of the watershed in this heterogeneous landscape remains strictly limited.

4.2. Determinants of Fuel Wood Use

For determinants of fuel wood use, the relationships of independent variables with dependent variable were largely as expected. Family size is positively correlated with fuel wood consumption, because bigger families need to cook more food, boil more water, and heat more space [14, 61]. *Marginal consumption* of firewood, however, diminishes with an increase in family size, supporting previous findings (15, 62, 63, 64, 65]. Education is negatively correlated with fuel wood consumption, either because educated people are aware of environmental consequences [66-67] or because education is correlated with higher incomes and the ability to afford alternative energies like LPG [61, 68]. Number of cattle is positively correlated with fuel wood consumption wherever stall-feeding is practiced, since feed preparation requires more fuel. Bigger herds have, however, also been correlated with stronger impacts on forests where they are grazed in forest [69]. The positive relationship of cattle number with fuel wood use is strongest in the relatively low-elevation Okaity villages, where stall-feeding is more consistent than in the higher villages. This may point to a significant trade-off between the promotion of stall-feeding to reduce open-grazing pressure on forests, and attempts to minimize fuel wood consumption. We are currently carrying out tests of this possibility in the Darjeeling area.

4.3. Determinants of Investments in LPG

Analysis for determinants of LPG also showed results as expected. People associate the cleanliness and consistency of LPG with higher levels of development, and tend to adopt it when they can afford it. This income threshold is probably correlated with living close to roads and around larger towns at lower elevations. Bigger families, however, tend to have somewhat weaker preference for LPG because cooking food for a large family with LPG is costly, and because large families use large pots, which do not fit easily on LPG burners. However, the role of demographic factors in adopting LPG is still poorly explored and requires further investigation [14]. It is important to note that in rural areas, LPG adoption is generally seen as a complement to the fuel wood stove, rarely as a substitute for it. Thus many households continue using fuel wood even when they have an LPG stove available for special occasions or special dishes.

In general, low-income families are less likely to purchase LPG than better-off families, due both to the expense [5, 14, 15, 25, 70] and because alternative energy technologies are relatively difficult to operate [31]. Affiliation with social organizations and access to television are positively correlated with LPG adoption, either because such exposures directly motivate adoption of cleaner energy or because such exposures are indirectly influenced by education and income. Our results thus support calls for investment in a number of social and economic factors in order to promote the transition to LPG use in rural areas [71].

4.4. Implications of Fuel Wood Harvest

Several studies have argued that firewood collection is a major cause of deforestation in developing countries (1, 2, 71]. Although the relationship between supply and demand for biomass fuels is seldom straightforward [22], there is a risk that constantly growing demand may drive harvest above locally sustainable levels in many places [9-11]. The World Bank [13] estimated that in India, as much as 41% of forest degradation is accounted for by biomass harvest. Singh [72] also suggested that while fuel wood users in India are declining as a percentage of total population, the absolute number of people using fuel wood continues to increase due to rural population growth. Intense biomass harvest produces thin, fragmented and patchy forests, which may then be further converted into agricultural land, open pasture, and other developments. Loss of forest cover leads to ecosystem degradation, habitat disruption and biodiversity loss. Preferential harvest may lead to an increase in homogeneity in areas with endemic, endangered, and rare taxa. Local fuel wood shortages can also have serious social implications, especially for the women and children who may need to expend extra time and energy in fuel wood collection.

To cope with local shortages, people often resort to burning other biomass (known locally as *jhikra*) such as small twigs of wood, bamboo or tea, maize stalks and other crop waste. Such biomass burns easily but produces little heat or useful coals, while emitting much smoke and reducing the amount of biomass available for recycling back into agricultural fields as green manure. At the same time, such biomass is itself becoming scarcer over time, due to changes in agricultural practice.

4.5. Comparison of Determinants Between Nepal and India

Our results suggest that people on the Nepal side of the border consume significantly more fuel wood *per capita* than do people in India. The most important determinants of this difference seem to be household income and number of cattle. Considerably lower household incomes in Nepal mean that people will hesitate to take on the extra expense of LPG. In addition, cattle are a more significant part of household income on the Nepal side, since a ban on open grazing associated with the gazetting of the Singalila National Park in 1992 has constrained livestock husbandry on the Indian side.

Government-sponsored forest management groups and environmental TV programming in Nepal seem to be playing little role in limiting fuel wood consumption. Time spent collecting fuel wood is higher for people in Nepal side, partly because many forest lands are already overexploited. The quality of the fuel woods in use in Nepal might also be lower than in India, because good quality woods have already been overexploited on the Nepal side. Poor quality woods burn more quickly and produce less heat, causing people to consume more fuel wood. Finally, traditional open wood-burning stoves are relatively inefficient. Improved versions with chimneys are available and should be strongly promoted in this area, both to reduce fuel wood use as well as to support respiratory health.

5. Conclusion

Firewood is still the main source of household energy in rural Eastern Himalaya, as it is throughout the developing world. In the Himalayas, LPG is only gradually being adopted. A range of social, economic, and policy factors influence the decisions of households regarding fuel wood consumption and the adoption of LPG. It has been suggested that firewood collection is the major cause of primary deforestation in the region. Continued increase in the rate of preferred species collection may already have outstripped the regenerative capacities of several tree species. Increased emphasis on community-led planting of locally preferred species is important to help curtail ongoing reductions of forest cover and loss of regional biodiversity. Scarcity of fuel wood in sensitive areas is resulting in increased use of low-quality and scarce alternative biomass; people are thus put in double jeopardy.

One means to alleviate fuel wood pressures in remote hill areas of the Nepali-speaking Eastern Himalaya, where LPG is inaccessible, would be to encourage the widespread adoption of Improved Cook Stoves such as the locally designed and constructed *Tamang*–style stove from Nepal. The Nepalese National Rural and Renewable Energy Programme (NRREP) has set a target of distributing 475,000 of these stoves within Nepal by 2017. Using only locally available materials, and conforming to the requirements of Nepali traditional cooking, these mud-ceramic stoves have an external chimney and improved combustion efficiency. They have undergone testing to international standards in Nepal, showing marked improvements over their traditional counterparts in emissions of CO and particulate matter, as well as surprisingly large correlated improvements in household health status. The stoves are well-received, even aspirational, goods. Yet, they are unlikely to be a commercial success in the conventional sense, since (like their traditional counterparts) they are designed to be permanently installed in kitchens, and are labor-intensive to construct. Although these stoves are being successfully promoted in Nepal by the Alternative Energy Promotion Centre (AEPC) and few other organizations, they will need to be distributed outside Nepal via promotion primarily within and among rural communities.

In summary, *per capita* fuel wood consumption rates are modest where families remain in the traditional extended family structure, but current trends are toward nuclear family units in urban and rural Eastern Himalaya. Education, income enhancement, and reduced family size are all associated with reduced total fuel wood consumption rates and with enhanced adoption of LPG. These trends should continue to be promoted, both for people's well-being and for improved forest condition. Trends toward lower livestock numbers per household, and use of market-bought concentrated cattle feed to supplement forest-gathered feed, are advancing gradually in many parts of the Himalayas as rural-urban employment migration increases. However, note that there may be significant trade-offs among some of these indirect measures, and many depend on increased rural-urban commercial interdependency.

Planting mixed-species wood-lots with useful fodder and firewood species around villages can minimize the negative impacts of fuel wood consumption on forests, especially on the Nepal side where forestland is already sparse. Better-insulated housing systems can reduce fuel wood use for space heating, but this depends on increasing household incomes as well as awareness. Improved cook stoves, too, must continue to be promoted widely in parts of the hill districts of Nepal and India where rural road networks have not reached. Importantly, partial subsidies for low-income households to access LPG and other environmentally friendly energy technologies are still needed to stimulate adoption rates.

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