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Research article

Firewood consumption and extraction from community forests in East Khasi Hills District, Meghalaya: Its impact on woody species diversity and population structure

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Abstract: Firewood serves as the principal source of energy for cooking and heating, for many rural communities, but the impact of firewood extraction on the forest is often undermined. The present study was undertaken to assess the firewood consumption pattern by households living near community forests of East Khasi Hills District, Meghalaya and the impact of such activity on species diversity and population structure on such forests. Data on firewood consumption and preferred firewood species, and impacts of firewood harvesting on species diversity and population structure were collected through household surveys and phytosociological studies respectively. The surveyed households showed high dependency on firewood and the consumption pattern varies with the family size. The preferred firewood species are those of hardwood trees such as *Quercus* spp., *Lithocarpus* spp., *Castanopsis* spp. and *Myrica* spp. Firewood extraction have negative impact on forests, resulting in decrease in species diversity and population of the preferred firewood species. Statistical analysis revealed that species richness and diversity and density differ significantly in protected and unprotected forests. Despite low per capita consumption of firewood and precautionary measures like regulated harvesting in the study area, firewood harvesting cannot be ignored as an important cause of forest degradation and biodiversity loss. More research into local ecological and cultural contexts and perceptions concerning costs and benefits can help devise sustainable management options, including alternative sources of fuel.
Keywords: Firewood harvesting - Local communities - Energy source - Protected forest - Species richness - Biodiversity loss.

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INTRODUCTION

Firewood is an important source of traditional energy for majority of the people in developing countries (San *et al*. 2012, Specht *et al*. 2015). Mainly used for food preparation and heating, this energy source is most commonly preferred by people living in mountainous and rural areas chiefly because it is cheap, freely and easily accessible and easy to use (Chettri *et al*. 2002, Bhatt & Sachan 2004). Moreover, in such areas due to poor socio-economic conditions, lack of transportation, high prices and limited supply, other forms of commercial energy are beyond the reach of ordinary people (Madubansi & Shackleton 2007). Majority of India's rural population depends on firewood from natural forests as their principal source of fuel for heating and cooking (Bhatt *et al*. 2016). Worldwide studies revealed that extensive harvesting of firewood by communities has been exerting pressure on the forests, causing continuous loss of biomass which poses threats to the biological resources in the area and greatly hamper the local economy (Ruger *et al*. 2008, Specht *et al*. 2015).

Meghalaya is a hilly state in the Northeastern Region of India with about 80% of its population living in the rural areas (Anonymous 2017) and 76.3% of its land under forest cover (FSI 2019). As with majority of the

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north eastern states, Meghalaya too has about ninety percent of its forests under the community control and management (Poffenberger 2007). The local people develop various types of traditional forest management practices which contributed to the conservation of biodiversity and addressing the livelihood needs of the rural people (Tiwari *et al*. 2010, Tynsong & Tiwari 2011, Lynser & Tiwari 2016). Rural households in Meghalaya depend heavily on firewood for cooking and heating purposes (Lynser 2013). A major portion of the firewood for household use comes from community forests, as firewood extraction from government forests is usually restricted. In areas where agro-forestry systems exist, a substantial portion of firewood comes from agro-forests.

Despite the fact that the state has got rich forest resources, rapid increase in population during the past few decades has led to an increase in firewood consumption resulting in the encroachment of forests for firewood. Though a number of studies on firewood consumption and its potential impact on forest biodiversity and structure are available from other parts of the world (Specht *et al*. 2015, Sassen *et al*. 2015) and India (Kumar & Shahabuddin 2005, Shaheen *et al*. 2016), similar studies are lacking in Meghalaya. The East Khasi Hills, one of the districts in the state has a low forest cover as compared to other districts and has witnessed a decline in the forest cover during the last two decades (FSI 2019). Recently, a number of studies have been carried out in community forests of East Khasi hills of Meghalaya to understand the importance of these forests to the communities' survival (Lynser & Makdoh 2018), to evaluate the species diversity and structure (Upadhaya 2015), biomass and carbon stock (Chaudhury & Upadhaya 2016), and also to understand the effect of human disturbance on woody species composition and structure (Mir & Upadhaya 2017). However, there are no studies on the effect of firewood consumption and extraction from community forests and its impact on woody species diversity and population structure in East Khasi Hills District, Meghalaya. Therefore, the present study was carried out to estimate the household firewood consumption by communities in East Khasi Hills district of Meghalaya. The study also attempts to examine if firewood extraction has any negative impacts on species diversity and structure of the community forests in the district. Understanding the impacts of firewood extraction on forest quality is important as it will assist in forest maintenance and management which will not only meet the energy requirements of the tribal folk but also to maintain the ecological balance in fragile eco-system of the region.

MATERIALS AND METHODS

Study area

The East Khasi Hills district of Meghalaya lies approximately between 25° 07′ & 25° 41′ N latitude and 91° 21′ & 92° 09′ E longitude. It has an area of 2820 km^2 and occupies 12.57% of the total area of the State. As per 2011 census, the district has a population of 8.26 lakh persons living in 1.61 lakh households and 55.6% of its total population lives in rural villages (Anonymous 2017). About 62.3 percent of the total geographical area is under forest cover (FSI 2019) with forest types ranging from sub-tropical broad leaf to pine forest (Haridasan & Rao 1985–87). These forests yield a wide variety of timber and non-timber forest products for commercial and subsistence use, contributing a good source of revenue and income to the people of the district (Tynsong & Tiwari 2011). About 90% of rural households in the district rely on firewood from the forest for subsistence use (Anonymous 2014). There are three classes of forests in the district- the State Reserved Forests and the State Protected Forests which comprised a very small percentage (1.04%) of the total forest cover in the district and the Unclassified Forests (mainly comprising of community forests) which forms a major chunk of the total forest cover. These community forests are managed by the local communities through traditional institutions who develop various traditional forest management practices to ensure sustainability of the forests (Mir & Upadhaya 2017). These forests are assigned different local names and serve a specific purpose. For example, the *Law Adong* and *Law Kyntang* are safety forests, specifically protected for biodiversity conservation, maintaining ecosystem services and the environment, whereas the *Law Shnong* and *Law Raid* are supply forests mainly meant to cater the day to day resources needs of the local population (Rodgers 1994)

For the present study, three sites (Dympep, Kyrphei and Wahmawpat) with similar vegetation type and where firewood extraction is done by the local communities were selected for detail analysis. Each site has at least two types of community forest - one which is accessible for firewood extraction by the local communities (referred in this study as unprotected forest - *Law Shnong* / *Law Raid*), the other where firewood extraction by local communities is restricted (referred in this study as protected forest - *Law Adong*) (Fig. 1). The study sites are abbreviated as Dy, Ky and Wa and the forest types *Law Shnong* as LS and *Law Adong* as LA.

Data collection

A preliminary household survey was conducted to assess the firewood dependency on forest and to estimate

the firewood consumption by households in the study area. Thirty households were randomly selected in each site and with the help of semi-structured questionnaires, quantitative and qualitative data on firewood consumption and harvesting within the area were collected. Firstly, the quantity of firewood consumed per household was estimated by asking the members of the household how many stacks of firewood do they use in a year. One stack approximately contains 1250 kg of firewood because one stack consists of 30–32 man loads with each load weighing about 40 kg. Secondly, qualitative data such as tree species preferably used for firewood, source, time of collection and household members involved in the collection was collected. Regarding the data on tree species preferably used for firewood, the interviewees were asked to name the tree species most commonly collected by the household for firewood purposes (Specht *et al*. 2015) and these were rated in a scale of 1 to 3 with 1 as highly preferred firewood species and 3 for low quality firewood species. Key Informant Survey was also carried out with knowledgeable people of different age-groups to acquire information on measures taken to minimize negative impact that firewood harvesting may have on biodiversity and forest in the area.

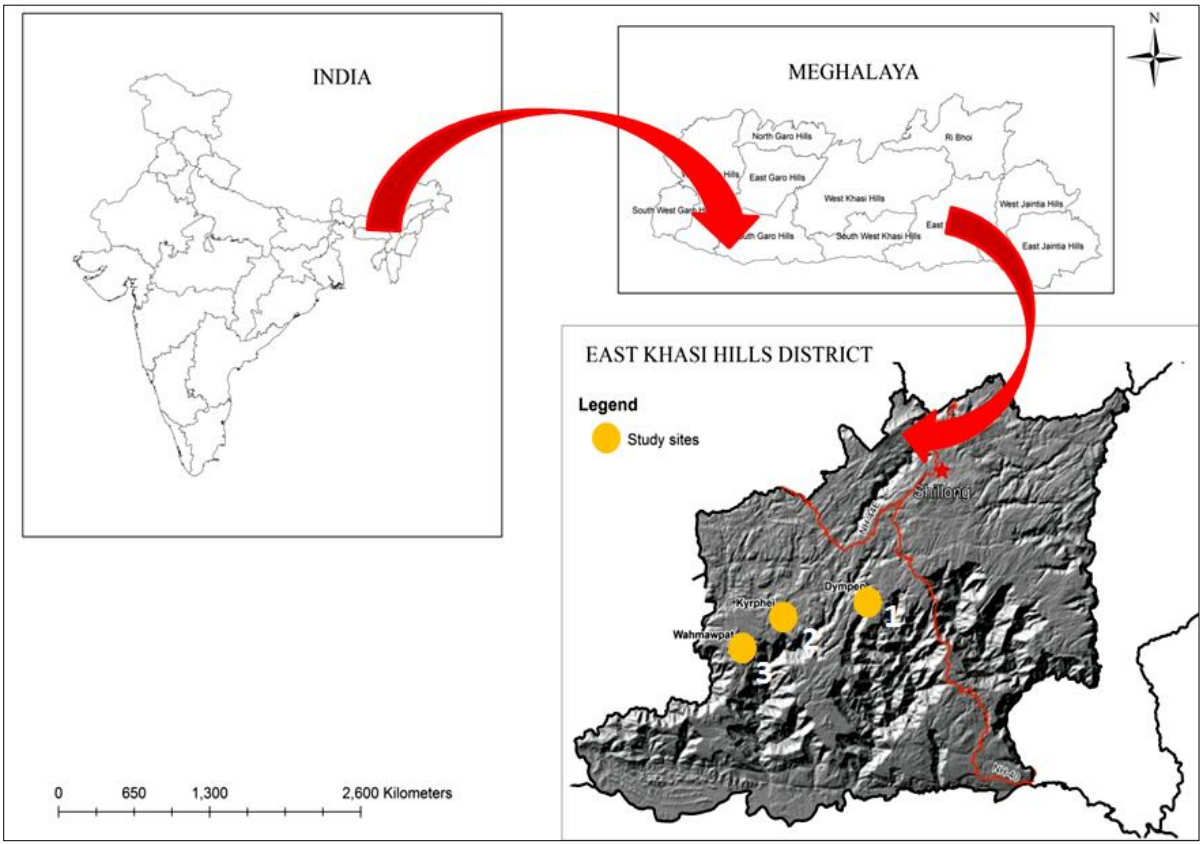

Figure 1. Location map showing the study sites.

To assess the impact of firewood extraction on woody species diversity and population structure, woody species ≥20 cm girth at breast height were sampled using quadrat method in two types of forests: Protected and Unprotected in each of the three sites. Altogether 6 forests were sampled by randomly laying thirty quadrats of 10 m × 10 m in each forest. Species were identified and densities of woody plants were determined. Trees with multiple stems and connected near the ground were counted as single individual (Ayyappan & Parthasarathy 1999). Specimens of all species were collected and herbaria were prepared following Jain & Rao (1977) and identification was done following Flora of Assam (Kanjilal *et al*. 1934–1940) and Forest Flora of Meghalaya (Haridasan & Rao 1985–1987). The nomenclatures of the species follows the regional flora. Important community parameters such as frequency, density, basal area and importance value index (IVI) of all the woody plant species were worked out by following Misra (1968) and Muller-Dombois & Ellenberg (1974). The species richness 'S' was obtained by listing all the woody species occurring in the respective forest following Whittaker (1972). The Species richness 'S' in all the forest was calculated using the formula:

$$D_{Mg} = \frac{(S-1)}{log\ N}$$

Where, D_{Mg} = Margalef's index, 'S' is the total number of species occurred and 'N' is the total number of individuals of all species.

The species diversity index (H') was determined by using the method given by Shannon & Weaver (1963):

$$H' = \sum_{i=1}^{s} pi \ln pI$$

Where, H′ = Shannon -Weiner diversity index, *pi* is the proportion of individuals in the *i*th species *i.e. (ni/N)*; *ni* = importance value index of the species; and *N* = importance value index of all the species.

To analyze the significance of variations in parameters such as species richness and diversity, stem density and the basal area between the different forest stands t test was done. Significance level p has been given consulting with the critical values of the t distribution (Zar 2004).

RESULTS

Household firewood consumption

Firewood is an important source of cooking fuel for the households in the study area. More than 98% of the surveyed households depend on firewood for meeting their basic cooking needs (Table 1). The quantity of firewood collected for self-consumption ranges between 0.63 to 5.0 tonnes per household per year. On average, each household collects about 2.43±1.08 tonnes of firewood per year which comes to 0.48±0.22 tonnes per person per year. It seems that households with larger family size collects higher amount of biomass for firewood, however when calculated on a per capita basis it is the smaller family size households who consumed more firewood (Table 2). Another observation was that households rearing livestock (especially pig) consumed more firewood. Firewood is collected mainly for subsistence use as large scale sale of firewood from the community forests is banned in the area. However, local sale in a small scale particularly by poor households within the village is allowed.

Table 1. Household firewood consumption in the study area (N=90).

Site	Total no. of HH	Percentage of HH collecting firewood from community forests	Firewood consumption (tones/HH/year)	Collection intensity (tones / year)	Use value
Dympep	70	97	2.83	198.1	S, C
Kyrphei	139	100	1.63	226.6	S, C
Wahmawpat	180	100	2.82	507.6	S

Note: *S-subsistence use; C-small scale commercialization, HH-House hold.

Table 2. Household size versus firewood consumption in the study area.

Household size	Members in a family	Firewood consumption (tones/HH/year)	Firewood consumption (tones/capita/year)
Large	>7	3.38	0.38
Medium	4-7	2.48	0.41
Small	1-4	1.73	0.52

Tree species used as firewood

On the basis of responses from the surveyed households, the list of tree species preferred as firewood by the local communities is given in table 3. The most preferred tree species as firewood are those belonging to the Fagaceae family like *Quercus* spp., *Lithocarpus* spp., *Castanopsis* spp. and *Myrica* spp. The next preferred tree species include *Elaeocarpus* spp., *Schima wallichii* DC. and *Wendlandia wallichii* W. & A. Others like *Exbucklandia populnea* Griff., *Camellia* sp., *Rhodendron* spp., *Garcinia* spp., *Photinia* spp. and *Eurya accuminata* DC. are also good for firewood use but they are not abundant or easily available. Species like *Engelhertia spicata* Leschen. ex Bl., *Aralia aramata* (G. Don) Seem., *Pinus kesiya* Roxb., *Helicia nilagirica* Bedd., *Symplocos* spp. are considered not suitable for firewood purpose; only in cases where people do not have any other option then these species are used as firewood. Almost all the surveyed households harvest firewood from the nearby community forests mainly during the dry winter months.

Table 3. Tree species preferred as firewood by the local communities.

S.N.	Tree species	HH collecting the species (%)	Preference Rating
1	*Aralia aramata* (G. Don) Seem.	43	3
2	*Camellia* sp.	78	2
3	*Castanopsis* sp.	100	1
4	*Elaeocarpus* sp.	76	2
5	*Engelhertia spicata* Leschen. ex Bl.	56	3

6	*Eurya acuminata* DC.	66	3
7	*Exbucklandia populnea* Griff.	61	2
8	*Garcinia* sp.	33	2
9	*Helicia nilagirica* Bedd.	51	3
10	*Lithocarpus* sp.	100	1
11	*Myrica* sp.	100	1
12	*Persea* sp.	33	2
13	*Photinia* sp.	56	2
14	*Pinus kesiya* Roxb.	80	3
15	*Quercus* sp.	33	1
16	*Rhus javanica* L.	50	3
17	*Schima wallichii* DC.	98	2
18	*Symplocos* sp.	67	3
19	*Syzygium tetragonum* Wall. ex. Kurz.	33	2
20	*Wendlandia wallichii* W. & A.	94	1

Impact of firewood extraction on woody species diversity and population structure

The vegetation survey revealed that there was a significant difference in species richness and density of trees in the protected and unprotected forest (Table 4). Overall species richness recorded in protected forests (82 species, 61 genera and 40 families) was comparatively higher to the unprotected forests with 52 species, 43 genera and 30 families. The Margalef species richness index differ significantly, it was 6.2 for protected forests while for unprotected forest it was 4.7. Protected forests recorded significantly higher mean tree density (2593 individuals ha^{-1}) than unprotected forests (1728 individuals ha^{-1}). The dominant tree species on the basis of density in the protected forest are those belonging to Fagaceae family, while the unprotected forests are dominated by species from the Proteaceae family. Similarly, the mean basal area was higher in protected forests (40.68 $m^2 ha^{-1}$) than unprotected forests (21.73 $m^2 ha^{-1}$) (Table 4).

Table 4. Diversity and community characteristics of woody vegetation in Protected and Unprotected forest of East Khasi Hills.

Parameters	**Protected forests**				**Un-protected forests**				**Significance**
	Dy_LA	**Ky_LA**	**Wa_LA**	***Mean**	**Dy_LS**	**Ky_LS**	**Wa_LS**	***Mean**	
Species richness	43	38	46	42.3 (±4.04)	32	25	31	29.3 (±3.79)	11.26*,**
Number of genera	39	27	38	34.7 (±6.66)	30	23	28	27.0 (±3.61)	4.13**
Number of families	28	21	25	24.7 (±3.51)	24	22	21	22.3 (±1.53)	1.4
Margalef's diversity index	6.1	5.5	7.1	6.2 (±0.82)	5.0	3.6	5.4	4.7 (±0.93)	6.52*,**
Shannon index	3.0	2.7	3.2	3.0 (±0.25)	2.9	2.4	2.8	2.7 (0.28)	3.02**
Density (stems ha^{-1})	2637	2957	2187	2593.3 (±386.82)	1743	2580	860	1727.8 (±860.11)	3.15**
Basal cover ($m^2 ha^{-1}$)	30.47	38.79	52.79	40.68 (±11.28)	18.92	32.70	13.56	21.73 (±9.87)	1.88

Note: Results of t tests: * = $p < 0.05$, ** = $p < 0.1$; * Mean±standard deviation.

Species richness, tree density and basal area consistently decreased with increasing girth class from 20 to 140 cm in both types of forests resulting in a reverse J-shaped curve (Fig. 2). Higher species richness and tree density was observed in protected than unprotected forest for all girth class. The distribution of basal area across different girth class in protected forests decrease with increase in girth class except for girth class 120–140 cm, while in unprotected forests it initially decreases upto the girth class 60–80 cm and beyond which the basal area was unevenly distributed (Fig. 2).

DISCUSSION

Majority of the households in the study area rely on firewood for meeting their basic cooking needs, consuming over 2.43 tonnes per household per year. These findings revealed a high dependency of the households in the study area on firewood which is similar to studies registered for other developing tropical countries such as Burma, Nigeria and Cambodia (San *et al*. 2012, Sein *et al*. 2015, Iheke & Osuji 2015). Household dynamics such as average family size and number of households has an influence on the consumption of firewood and smaller family size households consumed more firewood on a per capita basis (Knight & Rosa 2012). The amount of firewood consumed per capita recorded in this study is lower as

compared to similar studies in the region by Chettri *et al*. (2002) and Bhatt *et al*. (2016).

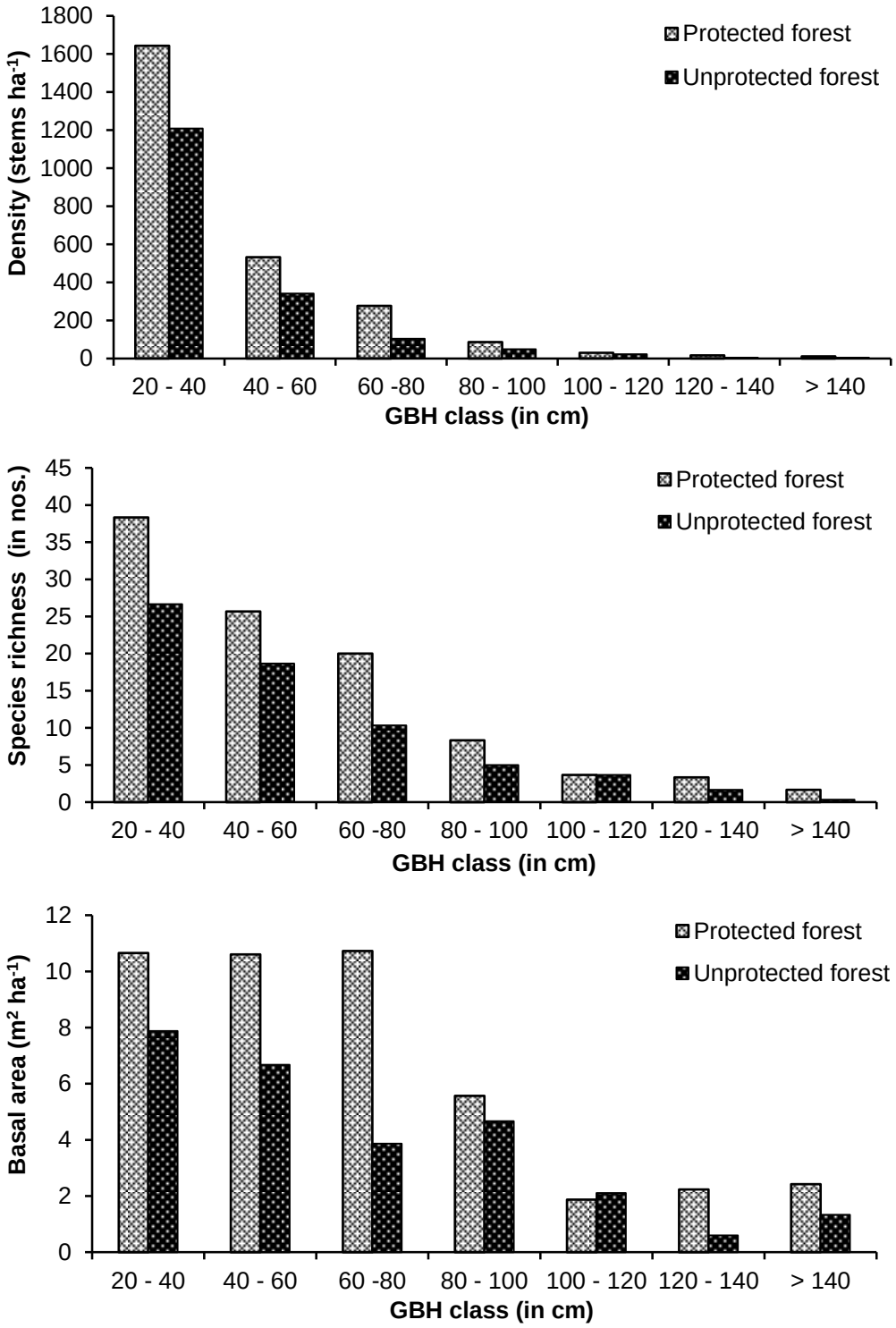

Figure 2. Density (stems ha^{-1}), Species richness (in nos), and Basal area (m^2 ha^{-1}) of woody species in different girth class in protected and unprotected community forests of East Khasi Hills District, Meghalaya, India.

Rural communities possessed good knowledge on woody species for fuelwood use (Ramos *et al*. 2008). For firewood purpose, *Quercus* spp. and *Lithocarpus* spp. are highly preferred as these are hardwood species and they burn for a longer time (Baroody 2013). Other species like *Schima* spp., *Symplocos* spp., *Elaeocarpus* spp and *Myrica* spp. are of slightly lower quality, but people harvest these as restricting only to tree species from the Fagaceae family may not be sufficient to meet the firewood need of the whole community. Species like *Engelhertia spicata*, *Aralia aramata* and *Helicia nilagirica* are not considered as good firewood as they produce less heat and burn out very fast. Only in situations when the preferred species are not conveniently located, people harvest these species for firewood use. Although available throughout the year, firewood is particularly collected during the winter months (Ramos & de Albuquerque 2012). During rainy season, the firewoods are

wet and heavy and because of the difficult terrain, their transportation is inconvenient. Moreover, firewood is needed year round, so huge quantity is needed to be collected and thus required the involvement of almost all members of the household. Winter months (November–February) are also considered to be the best time for collection as young family members (children) are free from their school schedule.

Human use of bio-resources such as firewood can result in a change in the tree communities (Specht *et al*. 2015). Tree species richness and density differed significantly in the protected and unprotected forests. The decreased in woody species richness and density in unprotected forests as a result of human activities and firewood harvesting in particular corroborates with studies by Tripathi *et al*. (2008), Tahoor *et al*. (2016) and Mir & Upadhaya (2017). The unprotected forests showed a markedly decrease in density of highly preferred firewood species like *Quercus* spp., *Lithocarpus* spp., *Castanopsis* spp. and increase in non-preferred firewood species such as *Helicia nilagirica* and *Engelhertia spicata.* Chopping of trees for firewood purpose can deplete the highly-preferred tree species (Sassen *et al*. 2015) and species composition shifted to tree species that are not used as fuelwood (Ruger *et al*. 2008). Our findings is in contrasts to that of Ruger *et al*. (2008) that with increasing levels of wood extraction, the stem numbers in larger diameter classes decrease whereas there is increase in the stem numbers in smaller diameter classes. This may be due to low harvesting level or that these changes can only be detected after decades or even centuries of repeated disturbance. Different views emerged from researches on implications of wood energy uses over the years. Researchers like Top *et al*. (2004) and Horst & Hovorka (2009) opined that wood energy dependence can provide important livelihood opportunities for rural communities and is not likely a significant cause of deforestation, while others like Davidar *et al*. (2007), Specht *et al*. (2015) & Sein *et al*. (2015) viewed firewood consumption as a major and chronic source of forest degradation. Despite the low per capita consumption of firewood and the presence of regulated harvesting measures in the study area, our results suggest that firewood harvesting cannot be ignored as an important cause of forest degradation and biodiversity loss.

CONCLUSION

Firewood harvesting in natural forests will continue to remain an important source of energy for the rural population in many developing countries. Our study reflects that even low level extraction with certain precautionary measures can still negatively impact forest structure and biodiversity. It is likely that the demand for fuelwood from natural forests will grow in the foreseeable future leading to intense forest degradation with negative consequences to the people who depend on the forest. More research into local ecological and cultural contexts and perceptions concerning costs and benefits can help devise more sustainable management options, including alternative sources of fuel. A decentralised management approach that builds on local institutions and understandings of the resource can help to maintain the ecological balance in rich but fragile eco-system of the region and poverty amelioration of a large part of human population that still depends directly on forest goods.

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