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Increasing Biotic Pressure on Available Biomass and Fuelwood and Promotion of Green Sources of Energy for Sustenance of the Himalayan Village Agro-ecosystems in the Chauparsa Watershed, Himachal Pradesh, India

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Abstract—*The present study is primarily focussed on estimation of available biomass and fuel wood consumption pattern from 9 village agroecosystems (36 households from 4 selected villages according to the altitude) of the Chauparsa watershed of the Kullu valley. The results have shown that there were 19 tree species identified in 40 randomly selected plots (20x20 m) where biomass ranged from 5.61 to 775.03 t ha^{-1} and Shannon – Wiener diversity index (H) from 0 to 1.73. While Simpson's dominance index (cd) for trees ranged from 4.63 (Picea smithiana) to 0.002 (Salix sp.). Here, higher values indicate relatively their higher dominance. Looking at fuelwood consumption pattern of the villagers, it ranged from 1.70 to 4.54 kg capita^{-1} per day^{-1} during summer and winter respectively. While per capita available forest cover in the watershed area was 0.89 ha indicating reasonably adequate in the villages. However, due to increasing anthropogenic activities, the preference of fuelwood tree species such as Buxus semipervirens, Picea smithiana, Toona ciliate, Quercus floribunda and Robinea pseudoacacia are coming under biotic stress. The study also indicates that fuelwood collection and consumption depend much on family size, distance from forest area and economic condition of the households. Looking at minimising the biotic pressure on these species, there is an urgent need to promote renewable sources of energy, improved ovens (tandoors), afforestation and implement wasteland development programmes in such areas as to sustain the rural economy and to maintain sound environment in the north western Indian Himalayan Region.*

Keywords: *Biomass, fuelwood consumption, biotic pressure, sustenance, green energy sources, north western Himalaya.*

1. INTRODUCTION

The Himalayan ecosystem is topographically fragile and ecologically delicate. It has diverse features in terms of maintaining ecological security of the Indian landmass. The Indian Himalaya is a home of a variety of forests, perennial rivers as a prime source of drinking and irrigation water, a clean source of energy such as hydropower, rich biodiversity, high value agricultural crops in terrace farming, and scenic features of landscape for sustainable tourism. Its vast green cover acts as a sink for carbon dioxide which is one of the most important ecosystem services provided by the forests. Forests and snow covers of the Himalaya act as a water reservoir and feed the major rivers of the Asia [8]. In India, rivers which originate from the Himalayan Region are the lifelines for more than 500 million people [4, 19]. In the Indian Himalayan region, amount of carbon sequestration is estimated to be 65 million tonnes annually in the above ground biomass alone whose monetary value stands to be Rs. 37.5 billion [26].

In the Himalayan region, land holdings are very small and productivity is very low. So the people are entirely dependent on the forests for their survival such as fuelwood, fodder, Non-Wood Forest Produces (NTFP), timber, etc. [25]. Fuelwood is the most preferred biomass in India in which 54 % of the total biomass is used from fuelwood itself [23]. The dependence of human population on fuelwood for cooking and water heating is so heavy that out of 6.6 million people, 4.31 million (64.8%) of the total populations are solely dependent on fuelwood [10].The over exploitation of the natural resources lead to the faster degradation of the Himalayan forests [14]. The impact of forest degradation is commonly seen as an increased amount of energy being spent by women in collecting fuelwood and water ([17, 19]. With the destruction of forest cover in the Himalaya, many perennial hill streams are drying up, frequency of floods are increasing during rainy season, extended period of droughts is affecting the huge amount of soil erosion, and ultimately low farm productivity at the end leads to poverty [10, 19].

Biomass is the largest energy source in rural India as around 80% of total rural energy consumption is met by fuelwood crop residues and animal residues which together are mainly used for cooking and heating [24]. With the uptake of clean energy, now the energy use pattern in rural India is changing. However, traditional fuels including fuelwood, crop residue and cow dung still constitute the main source of household cooking energy due to inadequate and unreliable supply of clean energy [2, 7]. Estimation of biomass consumption is highly variable because the major quantity of biomass could not be transacted in the market [22]. First time in India in 1965, Energy Survey Committee of India (ESCI) conducted studies on total energy consumption and its source of supply. The information on consumption of biomass based fuels was collected from 1962. In 1974, the Fuel Policy Committee (FPC) estimated the household use of commercial and non-commercial fuels and in 1976 the National Commission on agriculture projected the fuelwood demand up to the year 2006 [21]. In 1991, Food and Agriculture (FAO) of the United Nations estimated that the total primary energy consumption in India was 356 to 425 million tonnes of oil equivalent (mtoe) with the shares of biomass energy ranging from 36 to 46%. According to the Ministry of Environment and Forests (MoEF) report (National Forest Action Plan, 1999), fuelwood demand in rural areas varies with the changing climate, availability of other fuels, etc. The annual per capita fuelwood requirement in the country is estimated to be about 200 million tonnes. However, the annual per capita fuelwood consumption in the country varied from 0.20 to about 0.90 tonnes from warm to cold region respectively and its average value for the country is about 0.35 tonnes.

The total geographical area of Himachal Pradesh is 55,673 km² and its inhabiting populations are 6.85 million as per the 2011 census. In Himachal Pradesh, more than 90% of the total population is living in rural area. The total fuelwood availability in the state is about 15 million m³; while the total fuelwood requirement for the entire state is 1.26 million m³ per year [1]. In the cold dry temperate zone of Himachal Pradesh during winters, it requires more amount of fuelwood for space heating than cooking. Due to low connectivity with the urban areas of the region and a very less alternative options to replace their fuelwood demand for cooking, and water heating people still depends on fuelwood which is also due to its easily availability [3]. Keeping in mind these similar issues in mind, the primary objectives of the present study is therefore mainly to understand the fuelwood consumption pattern and preferences of wood species with a purpose to assess the highly threatened species in this environment and to quantify the amount of average seasonal fuelwood consumption in the Chauparsa watershed in the Kullu valley of Himachal Pradesh.

2. MATERIALS AND METHODS

2.1 Study Site

The Chauparsa watershed within the Lag valley falls in the Kullu district which is extended from 31°20.25' to 32°25.0' N Latitudes and 76°56.30' to 77°52.20' E Longitudes (Fig. 1). The nine villages (4 villages selected on the altitudinal basis) from the watershed were selected for the estimation of biomass available and fuelwood consumption pattern. The area selected for the study is representing between 1200-3000 metre above mean sea level and the geographic features of the region represent from mid hills to high hills in the region. The region also receives snowfall on high hills during winter months and serves as a great source of fresh water in the Beas basin of Himachal Pradesh. The ambient temperature ranges between 7.9°C to 25.6°C around the years. Temperature during Rabi (winter) season hovers around 12.7°C whereas during Kharif (summer) season average means temperature remains below 23.0°C. However, mean annual temperature remains 17.0°C in the region. While the average annual rainfall is 1111 mm [15]. Here, the main occupation of the people is agriculture.

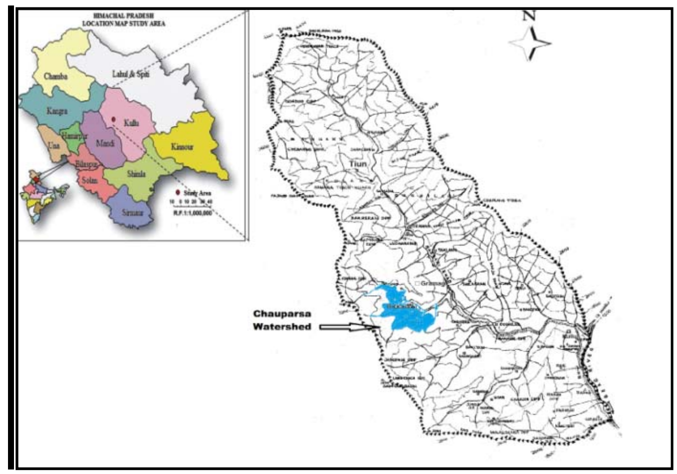

Fig. 1: Study site in Kullu district of Himachal Pradesh

2.2 Fuelwood consumption

Fuelwood is the main source of energy used for cooking, room heating and water heating in the hilly regions of the state. People living in this region are highly dependent on their nearby forests for firewood. Due to collection of huge amount of firewood, forests near the villages are subjected to rapid degradation and over-exploitation. A very small fraction of firewood comes from the agricultural fields [25]. To study the fuelwood consumption pattern in the study area, Participatory Rural Appraisal (PRA) method was carried out in the 9 representative villages. The four villages out of nine were finally selected for obtaining fuelwood consumption pattern in these villages according to the altitude (i.e., 3 villages at 2158 m, 2 at 2031 m, 2 at 1650 m and 2 at 1480 m) with the 36 households according to the family size during winter and summer of 2012. In this method, group discussion was done with a purpose to collect primary data about forest boundaries, households, number of members in a household, fuelwood collection pattern and preferences on fuelwood species, use of stoves used for cooking and heating and status of other renewable sources of energy.

To identify the fuelwood consumption pattern, kitchen performance test was done in which fuel–wood is weighed priory (i.e., 100 kg given for 5 days) and given to each household (HHs). Total consumption of the fuelwood was noted down after five days. In this way, total consumption of fuelwood per capita per day and total consumption of fuelwood for the entire season was calculated. Per capita consumption of the fuelwood is a dynamic entity and varies with time and space. The factors strongly influencing these variables are income level of the family, availability of clean and convenient form of energy such as liquefied petroleum gas (LPG), kerosene and electricity, use of fuel efficient cooking equipments, availability of fuelwood from the forests or other woody resources, relative price of the fuelwood vis-a-vis other energy forms, substitution of other fuels and climate [10].

2.3 Biomass Calculation

Biomass and carbon information are required to feed into carbon models, to assess changes in sequestration over time, and to evaluate the availability of bio-energy resources [9]. Use of biomass is not in itself a cause of concern. However, when resources are extracted unsustainably and energy conversion technologies are not efficient, there are serious adverse consequences for health, environment and economic development. For calculating the total biomass availability in the region, forests sampling was done with well distributed sample plots. Random sampling method was followed to laying out the plots (40 plots) in the area. Uniform quadrates were laid with the size of 20m x 20m. The numbers of tree species were counted in –each quadrate. Name, height, diameter at breast height was noted down. Trees with the Circumference at Breast Height (CBH) of more than 31.5 cm were noted down within the trees. Disturbance data was observed on the basis of number of tree lopping in a selected plot. Species wise total trees found lopped in 40 sample plots indicated their destruction numbers. In our present study, biomass was estimated by taking volume of biomass and specific gravity (SG) of the tree, as described below by [20, 12, 6].

$$\text{Biomass (t)} = \text{Volume (m}^3\text{) x Specific gravity}$$

3. RESULTS AND DISCUSSION

In the study area, it is observed that every village has their own traditional forests for collection of fuelwood and most of these forests are near the villages which are easily accessible. It is also observed that the forests which are near the villages are more degraded than the far away forests. This is because the villagers also want to lessen their labour as well as to save their energy because of its easily availability in the immediate surroundings of the villages. As far as the total forest area availability is concerned in the watershed, it stood to be 1300 ha indicating per capita forest availability as much as 0.89 ha. The availability of the forest resources is quite reasonable compared to other similar villages in other parts of the Indian Himalaya. However, the certain tree species are under biotic pressure due to their larger preferences to use for fuelwood and fodder (Fig. 2 a-d). The preferred tree species being used as fuelwood are *Buxus semipervirens, Picea smithiana, Toona ciliate, Quercus floribunda* and *Robinea pseudoacacia* showing their destruction numbers as 41, 21, 10, 11, 25 respectively. Preference of these species is also due to their use as fodder. The present study reveals that the use of fuelwood was 4.52 kg per capita^{-1} day^{-1} and 1.70 kg per capita^{-1} day^{-1} in winter and summer respectively (Table 1). These per capita^{-1} day^{-1} values of fuelwood consumption is noted to be higher than the other states like Andra Pradesh (0.52 kg), Arunachal Pradesh (1.15 kg) and Bihar (1.01 kg) [10]. This is mainly due to climatic variations from the south Indian and the Indo-Gengetic Plain to the mountain region. In addition, high prices of LPG, less economic non-conventional energy sources like solar power, wind energy, and above all villagers' comfortability and convenience have been the other influencing factors to make popular the frequent use of fuelwood from the surrounding forest resources. The increased use of fuelwood in winter in the mountain region is mainly for space heating, water heating and cooking.

It is noted that amount of availability of fuelwood significantly influences its consumption (Fig.3). It is found that the village with the adequate forest resources has almost twice the normal per capita consumption of fuelwood as compared to the villages which do not have any forests [18]. In India, about 1.3 million of people, among which mostly women and children, die prematurely due to indoor air pollution from biomass burning. At the same time, this is also fact that the percentage of electrified villages in India has increased significantly from about 40% in 1980 to 87% 2001 [5].

Fig. 2: (a) Traditional earthen stove (*Chullah*), (b) metal stove (*tandoor*), (c) fuelwood collected from the surrounding (*Rubinea, Quercus*), and (d) lopped logs of trees from forests (*Pinus*).

Table 1: Fuelwood consumption pattern in the Chauparsa watershed in the Kullu valley

Total number of villages	9
Total number of households	286
Total population	1459
Total forest area (ha)	1300
Per capita forest availability (ha)	0.89
Fuelwood consumption during winter (per capita^{-1}day^{-1}, kg)	4.54
Fuelwood consumption during summer (per capita^{-1}day^{-1}, kg)	1.71

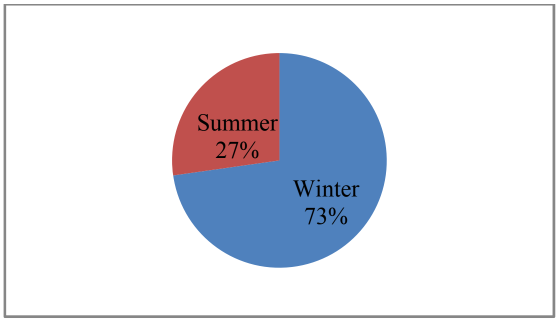

Fig. 3: Average seasonal pattern of fuelwood consumption based on per day estimation in the Chauparsa watershed.

During biomass calculation, total 19 species of trees were found in 40 sample plots (20x20 m) (Fig. 4; Table 2). In the study sites, biomass values of tree species available in the sampled plots ranged from 5.61 to 775.03 t ha^{-1}. As a result, Shannon – Wiener diversity index (H) ranged from 0 to 1.73 (Table 3) indicating a great difference from one species to other. The average biomass was calculated about 211.91 t ha^{-1} and total biomass available in the entire watershed was estimated to be around 275508 t ha^{-1}. While Simpson's dominance index (cd) for trees ranged from 4.63 (*Picea smithiana*) to 0.002 (*Salix sp.*) showing their greater extent of variability. The tree species *Buxus semipervirens, Picea smithiana, Toona ciliate, Quercus floribunda* and *Robinea pseudoacacia* were found as the most preferred fuelwood species and their numbers were found quite higher as these were largely disturbed and damaged within the sample lots.

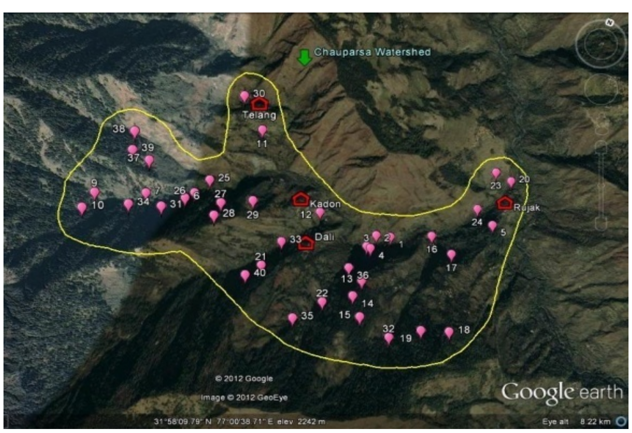

Fig. 4: Determination of sample plots in the Chauparsa watershed area

4. CONCLUSION AND RECOMMENDATION

- Fuelwood is the primary source of energy in the area which is also due to its easily availability and free of cost to the villagers from their surrounding villages. Use of renewable source of energy is very poor in the area which is also due to poor supply of LPG and electricity and socio-economic status of the households. Therefore, promotion of energy efficient cooking stove/metal ovens (*tandoors*) and other renewable sources of energy are recommended to make popular in the area.
- The tree species such as *Buxus semipervirens, Picea smithiana, Toona ciliate, Quercus floribunda* and *Robinea pseudoacacia* are under biotic pressure. It is therefore a need of the hour to promote also such other similar tree species in the watershed development programmes as to provide fodder and fuelwood to sustain the rural economy and conserve forest resources in the villages. The social forestry needs to be promoted with the joint activities and participatory approaches with the villagers by way of afforestation, reforestation and forest rehabilitation techniques.
- The impacts of climate change are looming over the horizon, coupled with the increase in energy demand. Hence, a concerted effort in this direction has to be taken to ensure availability of clean fuels and better energy devices so as to prevent environmental degradations and health ailments in the Himalayan Region.
- Capacity building of the villagers on the environmental conservation issues is also one of the fundamental steps to implement for the sustainable use of bio-energy resources.

Since fuelwood would be a constant primary source of energy in the area, its possibility should be looked into mainstreaming the use of biomass as efficiently as possible at every household level. It can therefore be argued that efficient handling and management of biomass with all its complexities can substantially meet the ever increasing demand of the villagers through decentralized energy systems leading to a greater energy security to them.

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Table 2: Tree species showing the number of disturbance in sample plots, and Simpson's dominance index

Taxa	Vernacular/ Local Name	AR (m)	LF	No. of disturbance	Simpson's dominance index
Abies pindrow	Tosh	2500-3800	T	4	0.50
Aesculus indica	Khanor	1800-3660	T	8	2.62
Alnus nitida	Bash	1000-2700	T	5	1.62
Buxus sempervirens	Papri		T	41	0.99
Cedrus deodara	Dyar	2200-2800	T	8	3.78
Celtis australis	-	500-2500	T	1	0.07
Cornus macrophylla	-	1000-2700	T	2	0.05
Eugenia jambolana	Jamun	Up to 1300	T	-	0.02
Juglans regia	Akhrot	1000-2000	T	-	0.15
Picea smithiana	Rai	1400-3200	T	21	4.63
Pinus wallichiana	Kail	2000-3500	T	8	1.26
Populus ciliate	Popular	1700-3000	T	-	0.02
Quercus floribunda	Mohru	2100-2400	T	11	2.26
Quercus leucotrichophora	Ban	1200-2200	T	3	0.87
Robinea pseudoacacia	Rubinea	1000-1500	T	25	0.49
Salix alba	-	1500-2000	T	1	0.002
Taxus wallichiana	Rakhal	1800-3300	T	2	0.01
Toona ciliata	Daral	0-1500	T	10	0.73
Ulmus wallichaina	-	1300-2500	T	-	0.30

Table 3: Number of plots showing available biomass

Plot No	Biomass (Tonnes/ha)	Shannon – Wiener diversity index	Plot No.	Biomass (Tonnes/ha)	Shannon – Wiener diversity index	Plot No.	Biomass (Tonnes/ha)	Shannon – Wiener diversity index	Plot No.	Biomass (Tonnes/ha)	Shannon – Wiener diversity index
1	203.11	0.85	11	507.56	0	21	512.45	0.34	31	184.30	0.67
2	352.33	1.73	12	226.40	1.15	22	11.78	0.88	32	22.59	1.07
3	56.94	1.03	13	53.46	1.42	23	138.26	1.30	33	533.95	0.68
4	284.96	0.72	14	756.25	0.36	24	8.05	1.41	34	352.43	0.97
5	98.38	0	15	119.44	0.69	25	5.61	0.95	35	43.65	0.68
6	57.88	0.67	16	72.27	1.29	26	41.10	0.88	36	37.93	0.67
7	80.44	1.32	17	160.04	1.16	27	154.70	0.84	37	530.56	1.09
8	500.45	0.52	18	96.75	1.17	28	64.03	0.68	38	74.71	1.46
9	343.25	1.21	19	59.52	1.31	29	5.61	0.69	39	534.13	0.66
10	328.77	1.53	20	59.54	0.73	30	28.85	1.02	40	775.02	0.69

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