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Estimation of forest biomass flow in the Montane mainland of the Uttarakhand Himalaya

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Abstract: Forests are the major source of timber, fuelwood, fodder, and food for the native people of the Himalayan region. Here, dependency of human population on the forest biomass for running their livelihood is tremendously high and it is a century old practice. Raising animals in the vast grasslands – temperate and alpine as well as collecting fodder through lopping fodder trees from the temperate forest, occupies the foremost place in the occupation and economy of the region. Forest biomass consumption varies from 13 kg/day/households (fuelwood) and 12 kg/day/household (fodder) in the lower elevation (1150 m) to 28 kg/day/household (Fuelwood) and 34 kg/day/household (fodder) in the higher elevation (1900 m). This paper examines the forest biomass-flow estimation in the montane mainland of the Uttarakhand Himalaya. Case study of eight villages of Kewer Gadhera Sub Watershed was carried out. Data were gathered through household level survey and participatory observation method and forest biomass estimation and withdrawal were calculated by conventional method. The study reveals that fodder and fuelwood withdrawal is a very common phenomenon in the study area and is a main livelihood option. Its consumption varies in different locations and seasons. It is also influenced by the aspect of slope. North-south facing slopes consumes more fuelwood than North-east facing slopes because due to variations in temperature.

Keywords: Forest biomass, fuelwood, fodder, montane mainland, grassland, Uttarakhand Himalaya

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Introduction

Biomass includes agricultural crops and trees, wood and wood residues, grasses, municipal residues, and other plant and plant-derived matter with its variety of applications, including bioenergy, liquid biofuel production, residential heating, industrial heat, and processing energy (Christopher et al, 2009). Meanwhile, forest biomass potentially including fuelwood, timber wood, fodder, grasses, medicinal plants, and other non-timber forest products (NTFP) represents a key component of available national and regional biomass supply. Humans have used forest biomass, in the form of fuelwood and fodder, from time immemorial. Even today, fuelwood is the world's largest single forest product: about 40% of the 3 billion m^3 of wood removed from forests around the world for all uses in 2005 was burned as fuelwood, and an additional 7 million m^3 of fuelwood caine from other wooded land (FAQ 2006).

Forest biomass withdrawn and consumption depends on the geo-environmental and socio economic conditions. In the Uttarakhand Himalaya, forest biomass is withdrawn and consumed largely from the pine *(Pinus wallencia)* and oak *(Quercus himalayana)* forests for fuelwood, fodder, and cutting of grasses from the mid-altitude for stall feeding. In addition; pine, oak, and deodar (*Cedrus deodara)* trees are useful for making houses and furniture. Pine grows between 1000 m and 1800 m, oak forest between 1800 to 2200 m and deodar >2200 m. Grasses grows from 1000 m upto 3200 m. Forest biomass flow occurs from the highlands to the mid-altitudes as fuelwood and fodder from lopping of oak and black mulberry (*Morus spp.)* trees. Pine wood and grass biomass flow from the surrounding of villages in the lower elevation and mid-slopes. In terms of the utilization of forest biomass, it can be categorized into two forms; under utilized and over utilized. The economically viable forest biomass –

temperate coniferous forests (deodar, spruce, and silver fir *(Abies pirdrow)*) is severely under utilized because of their inaccessibility while these types of forests have high biomass value. Pine and oak forests are overused and are depleting. These forest species are highly useful for fuelwood and fodder and they are accessible for the villages located in the lower elevation and mid-altitudes. But in terms of the present trends of forest biomass the pine and temperate coniferous forests have the highest biomass followed by oak forests and grasslands including alpine pasture. Large-scale forestation of pine in the valleys and mid-altitudes by the Department of Forest for the last two decades led to increase in the area of pine forest though it is the main source of fuelwood and timberwood for the study region. Increase biomass of temperate coniferous forest is due to inaccessibility of the regions where they grow. Grazing animals in the vast grasslands and in the oak forest areas are another important occupation of the native people. The purpose of this study is to estimate forest biomass and its flow, biomass withdrawal from the mountain niche, consumption pattern, and its impact on the environment and socio-economy of the case study villages located in the Kewer Gadhera Sub-Watershed (KGSW) of the Uttarakhand Himalaya.

Material and Methods

Study Area

KGSW of the Pindar Basin is located in the Uttarakhand Himalaya. It is extended between 30^o 6' N to 30^o 9' N and 79^o 18' E to 79^o 20' E. Total area of this watershed is 85.84 km^2. Forest covers 67.84 km^2 (79%) area. Out of the total forest cover, pine occupies 33 km^2 (48.6%) followed by oak forests including black mulberry; i.e. 20 km^2 (29.5%). Deodar, spruce, and silver fir occupy 10 km^2 (14.7%) whereas shrubs maintained 2.84 km^2 (4.1%). Grassland including alpine pasture has 2 km^2 (2.9%) area only. The region characterizes rich diversity in flora, ranging from pine in the lower and middle elevations to oak and coniferous forests in the higher elevations. Climate ranges from subtropical in the valleys (1000 m) to sub-temperate, temperate, and cold in the highlands (>3000 m). Summers are mild whereas winters are cold. During the four months of winters, heavy snowfall occurs in the highland regions. This increases fuelwood need. Highest rainfall occurs during the rainy season by the Southeast monsoon. Winter precipitation is caused by western disturbances. Landscape is undulating with gentle to steep slopes (10^o to 45^o). Narrow terraced fields that are used for agriculture and settlements are located along the perennial streams and on the gentle slopes. Kewer Gadhera is a perennial stream originates from the base of Kanpurgarhi and inlet into the Pindar River at Narain Bagar town. It flows with its four perennial tributaries. There are seventeen villages in this watershed with 6613 population (2008). Population density is three persons per ha, literacy rate is 61%, and sex ratio is 1085 female per thousand male. Traditional agriculture with cultivation of subsistence crops characterizes the economy. Subsistence crops are characterized by *barahnaaza* (twelve grains) grown together in a field. These crops have high agro-biodiversity meanwhile production and per ha yield is considerably low. The populace of the region tried to squeeze out from food insecurity thus out-migrated largely to the other parts of country. Major group of the people are engaged with agriculture and its allied practices. For centuries, they grow traditional subsistence crops and depend on the forest biomass for fuelwood, fodder, timber, and NTFP. With increase in population, pressure on agricultural fields and the forest areas has increased tremendously. Livestock farming runs parallel with agriculture and forms an important segment of economy. Traditional agricultural farming, forest biomass, and raising livestock altogether sustain livelihood.

Methods

This study was conducted mainly through collection of the primary data. Case studies of the selected villages (Eight in number) of KGSW were carried out. Household (HH) level survey was conducted through random sampling method on the bases of the involvement of people in collection of fuelwood, fodder, NTFP, and rearing animals in the nearby forest areas. A structured questionnaire was framed for HH level survey that includes the questions as per day withdrawal of fuelwood and fodder, number of animals goes for rearing in jungle, the areas where the people have daily and seasonal migration, and trees cut per day for this purpose. The empirical study is therefore focused on generating data pertaining to the parameters identified i.e., biomass withdrawn from the forests by women in the form of wood, lopped branches of treed and the grasses cut from the precipitous slopes and enclosed areas of mid-slopes. The villages and their respective forest areas where the community people interact were rapidly visited from March 2008 to Feb 2009. Participatory observation method was used to overview of forest status, their uses, distribution, and people's interaction.

Forest Biomass Estimation

Several convectional methods have been used to estimate forest biomass (Young *et al* 1964; Whittaker 1966; Ovington 1968). Some of the commonly employed techniques are (i) the harvest of average size trees either for the stand or within given size classes, (ii) the harvest of all materials in an unit area, and (iii) the harvest of individuals over a wide range in size and establishing the relationship between biomass and easily measurable plant parameters, such as, diameter and/or height. The height-diameter at breast height (h-dbh) relationship to biomass in forest stand is well formulated (Kira and Ogawa 1971). Ground based sampling in functional homogeneous vegetation categories is an approach which has found acceptability in the recent past (Shute and West 1982). For estimating total above ground biomass (dry wt.) natural ecosystem was divided into three components viz., trees, shrubs, and grasses. Ground sampling was carried out by laying sample plots in homogeneous vegetation strata. The quantitative measurements of plant parameters in these plots include girth at breast height (for trees) and height of individual plant. In case of shrubs and saplings, girth was measured at base (10 cm above ground). Tree individuals in each sample plot were categorized into girth classes of 10 cm interval.

Biomass values are usually quoted as oven dry weight in tones per ha or kg per square metre, although it can also be calculated in terms of the amount of carbon or fresh (green) weight, or as unit of heat. Biomass values represent the amount of organic material which has accumulated within an ecosystem. In general terms, higher biomass values are associated with more favourable environmental conditions; for example, warm, damp environments have higher biomass values than cool or dry environments which result in a period of inactivity. Biomass value is calculated in dry weight in kg/m2. Temperate grassland has 1.5, temperate forest has 30.0, pine forest and shrubs 6.0, and alpine meadow has 0.6 values (Jones ed, 1990). Based on the above calculation, biomass value was calculated in the study area. Highest biomass value is obtained from the temperate coniferous forest – deodar, spruce, and fir (52.31 t/ha, 52.00 t/ha, and 52.00 t/ha respectively) followed by pine 49.12 t/ha. Oak and black mulberry which are the foremost fodder trees in this area are valued 46.00 t/ha and 45.00 t/ha. Shrubs have 0.29 t/ha biomass and lowest is obtained by grassland including alpine pasture i.e., 0.09 t/ha. Table 1 shows homogenous vegetation unit, elevation, where these forest trees are grown, biomass in t/ha, area in ha and total biomass in tones. The plant species grow between 1000 m and >2200 m altitude in the study area. Area under different homogenous vegetation unit is also varied from 100 ha (Silver Fir) to 3500 ha (Pine). Oak and black mulberry have 2000 ha and 1500 ha area respectively. Though, biomass t/ha is the highest of coniferous forest, their area is considerably low i.e. 700 ha for deodar, 200 ha for spruce, and 100 ha for silver fir. Similarly, when we look upon the total biomass of forest, pine has highest 171920 tonnes, followed by oak 92000 tonnes. Black mulberry has 67500 tonnes, deodar has 36617 tonnes, and spruce has 10400 tonnes biomass. Grasses including alpine pastures, have lowest biomass (18 tonnes). This is followed by shrubs (82.36), while silver fir, which has highest biomass value, has only 5200 tonnes biomass in the study area. Silver fir and spruce grow in the high elevation and the area they grow is considerably less.

Table 1: Biomass of different vegetation types estimated by multistage statistical technique

Homogenous vegetation unit	**Elevation (m)**	**Biomass (tonnes/ha)**	**Area (ha)**	**Total biomass (tonnes)**
Grassland (inc alpine pasture)	1000->2200	0.09	200	18
Indigofers spp. (Shrubs)	1000-1800	0.29	284	82.36
Morus spp. (Black Mulberry)	1800-2200	45.00	1500	67500
Quercus himalayana (Oak)	1800-2200	46.00	2000	92000
Pinus wallencia (Pine)	1000-1800	49.12	3500	171920
Picea Smithiona (Spruce)	>2200	52.00	200	10400
Abies pirdrow (Silver Fir)	>2200	52.00	100	5200
Cedrus deodara (Deodar)	>2200	52.31	700	36617
Total		**37.10***	**8484**	**383737.4**

Source: Data collected and calculated by the author.

*Average biomass tonnes/ha

Forest Biomass Withdrawn

The biomass withdrawn from the forest includes the lopping of the trees for fuelwood (branches) and fodder (leafs) and the cutting of the grasses from sloppy precipitous surface as well as from the enclosed areas. The study has been conceived to assess the biomass withdrawn for the forests from these two accounts. The data regarding the consumption of fuelwood was generated by conducting intensive field work in the case study villages. The consumption patterns of wood were observed. Enquires were made and actual wood consumed in different months was actually weighted before being released for the use in the selected HH. All this was made possible by taking into consideration certain households representing different social and economic strata and were thus made sample households in the villages. On the basis, an average consumption of fuelwood per HH was arrived at which was then multiplies by total number of HH to get total consumption or conversely total withdrawal of biomass from the forests as fuelwood. An assessment of grass biomass of so withdrawn from the forest has been attempted. The assessment of the lopped biomass was made by actually weighing the lopped branches of trees by the people, selected as a sample cases for seven days and then working out an average per households per day. However, the samples were selected randomly. On the basis of the average, the assessment of the total biomass withdrawn by loping was made possible for the entire study villages. Grasses withdrawn from August to October (92 days) are meant for stall feeding to the cattle during the intense winters. Although, the requirement of stall feeding varies depending upon the number and type of animals kept by a household and yet everybody wants to store as much grass as possible because it finds readily available local market too. Thus, the storage of grass biomass is independent of requirement and assumes an almost uniform pattern. In such a situation, the assessment was made by surveying the green grass withdrawn by single households. While surveying, cattle was taken to assess as accurately as possible, the volume amount of grass stored. Thereafter an average for a household was worked out which when multiplied by total number of households would give us the total biomass withdrawn in the shape of grasses. On the basis of the above discussion, particularly with respects to climatic condition, a working schedule for biomass withdrawn was worked out.

Fuelwood

Forest is the only principal source of fuelwood collection. Generally, females collect fuelwood. The summer season is the optimum time for collection of dry wood. Seldom, fuelwood remains insufficient thus; lopped wood and fodder supplement it. There is a marked variation in the consumption of fuelwood in different months of the year. It has been found that the fuelwood consumption is lowest from May to September when fuel is not used for heating purposes. In the months of March, April, October and November fuel consumption is moderate. It reaches the highest during the three months of winter season i.e. December, January, and February. In terms of location of villages according to an elevation and aspects of slopes, fuelwood consumption varies tremendously.

Fuelwood consumption in the villages varies according to the aspects of slope, altitude, and accessibility from the road head (Table 3). Pine and oak forests are the main source of fuelwood. The villages located in the lower elevation, fuelwood is withdrawn from pine forest and its consumption is comparatively low (12 kg/day/HH) while the villages located in the higher elevation; fuelwood is withdrawn from the oak forest with high consumption (27 kg/day/HH). It is slightly higher (1-2 kg/day/HH) in the villages, located in the NW facing slope because these slopes receive comparatively low solar radiation. Average fuelwood consumption/day/HH is highest from the oak forest (22.7 kg) followed by the pine forest (14.3 kg) which is averaged 19.25 kg/day/HH. Three villages – Jhijodi (1900 m), Kaub (1600 m), and Swan (1900 m) receive snowfall during winters therefore the fuelwood consumption (mainly from oak forest), in these villages, is high. In terms of total fuelwood consumption, village Kaub placed first with 2208.25 tonnes/year, it is seconded by Jhijodi (1478.25 tonnes/year) because of highest number of HH and high altitude. Average fuelwood consumption in the case study villages is 5141.05 tonnes/year. It was noticed during the field visit that the villages, located in the low altitude and on the road head, liquefied petroleum gas (LPG) for cooking is becoming popular steadily.

Lopping

Lopping is a common practice in the villages. The experienced ones make certain consideration of loping (i) local content of branch lopped (ii) length of the branch and (iii) age of the branch. While in the field, it was gathered that with the increase in the age of the branch, its leaf content and overall weight increases appreciably and so does its length and hence is preferred. The intensive fieldwork has revealed that this practice is not carried out throughout the year and is restricted 244 days (Table 2). The head loads of lopped tree branches were weighted to assess the actual biomass withdrawn. The length of the branch measured revealed the variation between 70 cm to 1 m. Further, it was also observed that the head load of individuals varied appreciably. The average head load/HH calculated reveals that 22.3 kg of lopped biomass is withdrawn/day and 244 days. Out of the eight villages case studied, this practice is done by the HH of three villages. These villages are located in the higher elevation (>1600 m) where oak forests are abundantly found.

Grass Cutting

Grass cutting is another important activity of the villages. The climatic condition allows the animals to graze only for 182 days in a year at the best and for the rest of the year these livestock are stall fed. Crop residue is also used as fodder as stall feeding. The grasses are not available throughout the year; therefore the villagers look forward towards forests for lopping trees and cutting grasses available on the high and mid slopes respectively. It is pertinent to add that the grass cutting process starts from mid August and continues up to mid October. However, the grass is cut from the enclosed areas only after it attains its maximum growth in the month of October and yet the people continue to store the grasses cut from the precipitous slopes from August onwards. Average/day/HH grass cutting is 14.4 kg (Table 4). In the lower elevation, per day/HH grass cutting is higher 22 kg than to the higher elevation (7 kg). The grasslands are found mostly in the mid-altitude slopes and alpine grasslands are greatly unused therefore grass biomass is highly withdrawn from the middle and lower elevation slopes. In a nutshell, when we put lopping and grass cutting together, the villages located >1600 m withdrawal high biomass (975 tonnes to 1285.504 tonnes) in a year while it is low in the villages located in the lower elevation. It is because of that the number of animals is comparatively low in these villages and the people are involved in grass cutting only.

Table 2: Schedule for Biomass Withdrawal

Forest biomass	**Period of collection**	**No of days in a year**
Fuelwood	January to December	365
Lopping	Feb to June and September to November	244
Grasses	Aug, Sept., and October	92

Table 3: Average Fuelwood Consumption in case studies village of the KGSW in 2008

Village name	Slope aspect	Height (m)	Accessibility from road	Total HHs**	Fuelwood (in Kg) withdrawn/day/HH			Total biomass (in tonnes) withdrawn /year
					Pine	Oak	Total	
Kewer	NE	1150	1 km	26	12	-	12	113.88
Bhagoti	NE	1350	1 km	88	15	-	15	481.8
Keshwan	NE	1600	5 km	21	18	-	18	137.97
Jhijodi	NE	1900	10 km	150	-	27	27	1478.25
Ali	NW	1150	1 km	15	13	-	13	71.175
Bedula	NW	1300	3 km	36	16	-	16	210.24
Kaub	NW	1600	5 km	242	12	13	25	2208.25
Swan	NW	1900	8 km	43	-	28	28	439.46
Total				**612**	**14.3***	**22.7***	**19.25***	**5141.05**

Source: Primary collection of data, *Average of fuelwood comsumption **Census data 2008.
Abbreviation: NE= Northeast, NW= Northwest.

Table 4: Biomass withdrawn by lopping and grass cutting, 2008

Village name	**Total HHs***	**Biomass (in kg) withdrawn/day/HH**		**Total biomass (in tonnes) withdrawn/year**
		By lopping**	**By grass cutting*****	
Kewer	26	-	20	47.84
Bhagoti	88	-	22	178.112
Keshwan	21	-	15	28.98
Jhijodi	150	24	07	975
Ali	15	-	12	16.56
Bedula	36	-	20	66.24
Kaub	242	18	10	1285.504
Swan	43	25	09	297.904
Total	**621**	**22.3********	**14.4********	**2896.14**

Source: Primary collection of data, *Census data 2008.
**244 days in a year, ***92 days in a year, ****averaged.

Discussion and Conclusions

There are serious problems in determining total available forest cover; biomass productivity, biomass demands, and actual consumption, there are also conflicting estimates of the amount of forest/support land needed to support one unit of cultivated land. Growing fuelwood, fodder, and timber demands are the causes of receding forest perimeters around the habitations in the mountains (Bajracharya 1983). Most of the degradation of forest to unpalatable weeds stage is due to increased human and animal populations (Jackson 1983). In the montane mainland of the Uttarakhand Himalaya, forest resource depletion is mainly due to forest biomass flow from the highlands to the valley region to meet the various requirements of the population living in this region. The entire population depends on forest biomass for their livelihood. Forest biomass is excessively used during the winter months resulted in large-scale cutting of economically valued temperate trees. The populace of the region does not have any alternative source to replace the forest biomass for their daily uses. Besides fuelwood, fodder, and medicinal plants; forest products are largely used to assist agricultural practices. Rearing animals in the vast grasslands and collecting fodder leaves and green grasses is a centuries old practice. This resulted in environmental degradation – forest depletion and soil erosion.

While forest biomass energy has potential to provide non-fossil fuel energy, it should not come at the cost of sacrificing forest health and productivity (Simpson, 2009). It is clear that the current trend of forest biomass flow will lead to forest degradation. This problem could be avoided by prohibiting whole-tree harvesting on both private and crown lands, or by prohibiting biomass energy facilities from purchasing deadwood, tree tops, and branches as feedstock. Any forest biomass developments should be designed to benefit rural communities. This would require small-scale and regionally dispersed facilities that are at least partially community-owned. The available science is clear that stand-wide whole-tree harvesting (i.e., removing branches, tops and foliage as well as stem wood) and removal of deadwood has significant detrimental impacts on soil nutrients, soil organic matter, forest productivity, wildlife habitat and forest carbon storage. The straight-forward way to avoid these threats to forest sustainability is to leave the tops and branches of harvested trees in the forest, along with standing and fallen deadwood. It is recommended that biomass harvesting for fuel wood and fodder not include whole-tree harvesting or deadwood removal in order to avoid the most serious ecological and forest productivity impacts associated with biomass harvesting. Any estimate of biomass availability and cost of feedstock, thus, should not include deadwood or tree tops and branches.

Looking into socioeconomic point of view, forest biomass is the only renewable energy source easily available to human being. But while forest biomass is a renewable resource, the availability of forest biomass is limited over short time periods by both the amount of land in forests and the rate of forest growth. Therefore, an increased use of forest biomass for fodder, fuel wood, and timber wood will likely impact all other users of the forest resource. Over the years, due to anthropogenic actions the size of the carbon pool has diminished (Bolin 1977; Woodwell 1978). History reminds us that population pressure and ensuing increased fuelwood extraction can cause localized shortages that lead to over – harvesting, deforestation, and other detrimental environmental impacts, which in turn can induce undesirable social and economic problems. Examples of civilization-limiting deforestation caused by biofuels extraction for industrial purposes (e.g., metal smelting) and domestic heating are evident from classical times onwards (e.g., Redman 1999, Williams 2001, Jacobs 2004, Diamond 2005). Forest biomass and its change over time have long been considered as key characteristics of forest ecosystems (Reichle 1982; Cannell 1982). The change in biomass stocks can be assessed either as a difference between the biomass increment and biomass removals or as a change of biomass stocks between consecutive inventories (IPCC 2003).

In the KGSW, degradation of natural forest is the main phenomenon particularly in the recent period. Excessive use of forest biomass as a form of timber, fuelwood, and fodder has resulted in environmental degradation. Fuelwood is required for cooking food and warming rooms. Mid slopes and the highlands are characterized by temperate and cold climates. Therefore, the fuelwood needs in these regions is high, particularly during the winter, when the highlands receive snowfall. Inaccessibility of the settlements does not provide a base for consuming other means of fuel such as LPG. Therefore, the dependency on the forest for fuelwood consumption is high and thus cause for deforestation. Though, considerable use of LPG and biogas took place mainly in the valley regions, it could not reduce forest biomass withdrawal. Since, the KGSW is characterized by primitive economy, which depends either on the production of subsistence cereal crops, livestock rearing or on forest biomass for fuelwood, fodder, and food need. For these basic requirements, natural forests are degenerating at a large-scale. Use of timber for building construction and making furniture is also a factor for degeneration of forests.

Fuelwood requirement can be reduced through establishment of biogas plants. In the valley regions it is quite successful. Pasturelands should be conserved through proper management. The areas where instability of land is high, plantation of trees can be done to stop erosion and restore vegetation. Fast growing trees should be planted to restore the fragile erosion prone landscape. Community land in surroundings of the villages can be used for growing grasses and plantation of fodder trees. This will lead to conservation of natural forest. There must be some scale of harnessing of forest biomass to reduce the unnecessary cutting of valuable trees. Community people participation should be ensuring to develop a methodology to conserve grazing land and to stop illegal felling of trees and grazing of animals. For that the entire forest land can be divided into the sectors and some sectors can be closed for three to four years with the help of community people. After that the closed forest area can be opened for one year to use biomass according to need base and the other forest area can be closed. This rotation will provide landscape stability, enough forest biomass, and reduce forest depletion. The Government also should assist the people to provide them widely used LGP reducing burden from the forest biomass.

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