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Biomass Distribution in Sub-tropical Forests of Solan Forest Division (HP)

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Abstract: The present investigation was carried out to study the distribution of biomass in different land uses viz., chir pine, ban oak, deodar, other broadleaves, culturable and un-culturable land uses, distributed in five Forest Ranges i.e., Dharampur, Parwanoo, Solan, Kandaghat and Subathu along altitudinal gradient from 900 to 2100 m of Solan Forest Division, Himachal Pradesh. The study reveals that out of 1.07 M t of total biomass in the division, the chir pine land use contributes 36.63%, ban oak 32.78%, other broadleaves 28.94%, deodar 1.15% and culturable land 0.48%. Along altitudinal gradient, it was 44.89% in 1500-1800 m, 42.38% in 1200-1500 m, 10.35% in 1800-2100 m and 2.36% in 900-1200 m elevation. The Dharampur Forest Range accounted for 31.60%, Parwanoo 27.38%, Solan 25.77%, Kandaghat 11.22% and Subathu 4.01% of the total biomass.

Key Words: Biomass, Forest Range, Forest Division, Land use, Altitudinal gradient, Digital Elevation Model (DEM)

The biomass information are useful to (i) quantitatively describe ecosystems and indicate the biomass resources available, (ii) quantify amount of nutrients in the ecosystem and hence elucidate nutrient cycling (Baker *et al.*, 1984, Brown, 1997 and Lim, 1988), (iii) determine energy fixation in forest ecosystems (Satoo, 1968), (iv) provide estimates of the carbon content in forest (Brown and Lugo, 1984, Brown *et al.*, 1989), (v) quantify increment in forest yield, growth or productivity and assess changes in forest structure (Brown, 1997). By using information on biomass, content of carbon, energy and nutrient could be estimated rapidly. This is also important for evaluation and improvement of site and these form the basis for sound forest management.

Tree biomass can also be an energy source to substitute the use of CO_2-emitting fossil fuel. Renewably grown biomass is a carbon-neutral fuel with low sulphur content and can be converted to electricity, heat, liquid and gaseous fuel. Plant biomass energy can contribute up to 45 million tonnes oil equivalent per year. This renewable carbon-neutral biomass energy could reduce CO_2 emission by 50 million tonnes (Mt) of carbon per year (Hall, 1998).

Forest can be a carbon source/sink and management of the forests can affect the global carbon cycle and climate change. In a review by Brown (1997), approximately fifty per cent of the biomass is carbon. This represents the potential amount of carbon that can be added to the atmosphere as CO_2 when the forest is cleared. According to Tipper (1998), deforestation contributes about 1.8 Gigatonne Carbon (Gt C) per year. On the other hand, forests remove CO_2 from the atmosphere through photosynthesis and an estimated 1.1 to 1.8 Gt C per year can be sequestered in 50 years (Makundi *et al.*, 1998).

Unlike in the developed countries, we do not have biomass inventories and databank to monitor and enhance carbon sequestration potential of different forests. In India, attempts were made to access carbon sequestration at macro level (Ravinder, 1997). No attempts have been made so for to access the biomass and carbon sequestration at micro levels. Such kind of micro-level study is essential for sustainable forest management in the country where heavy degradation has been caused by anthropogenic activities and different forest management prescriptions of the past warranted in different periods of time to meet the local and national needs. Knowing the present status of the forest is essential and effort has been made in the present study to quantify the forest biomass of Solan Forest Division (HP).

MATERIAL AND METHODS

Study Area

The study was carried out in the Solan Forest Division of Himachal Pradesh, which is located between 30^0 45' 00" to 31^0 10' 00" N latitude and 76^0 55' 00" to 77^0 15' 00" E longitude, covering an area of about 57,158 ha. The climate varies from extreme hot in the lower elevation and extreme cold in higher elevations. Precipitation is in the form of rains mainly during rainy season. There are 538 compartments/ forests distributed in five Forest Ranges i.e., Dharampur, Parwanoo, Solan, Kandaghat and Subathu. The forests in Solan Forest Division have pure and mixed stands of chir pine and mostly confirm to Champion and Seth's Forest type 9 C1a - Lower or Shiwalik chir pine forests. They lie between 900-2100 m a.m.s.l. The over-storey vegetation comprises of *Pinus roxburghii, Quercus leucotricophora, Cedrus deodara, Terminalia tomentosa, Dalbergia sissoo, Pyrus* *pashia, Albizia chinensis, Juglans regia, Celtis australis, Acacia catechu*, etc., and the under-storey vegetation comprises of *Berbaris* species, *Prinsepia utilis, Indigofera* species, *Rosa* species, *Sarcococca saligna, Rubus* species, *Hydera helix, Euphorbia* species, etc.

Construction of Digital Elevation Model

The digitization work was done on GTCO Calcomp Digitizing Table using CARTALINX 1.2. The elevation data covered in ten Forest Survey of India toposheets (1:25,000) were used to generate Digital Elevation Model (DEM). After digitizing contours at an interval of 100m, the contour coverage was then imported into IDRISI32. The CARTALINX 1.2 (Geographical information application system) and IDRISI 32 (Image processing and GIS software) have been developed by Clark Lab, Clark University, Worcester MA, USA. The vector contour coverage was then transformed into Triangulated Integrated Network (TIN). TIN is used to generate raster image surface with the module TINSURF. Finally vector contour coverage and TIN coverage was used to generate DEM (Raster layer). The DEM was then stratified into four elevation classes, i.e., 900-1200 m, 1200-1500 m, 1500-1800 m and 1800-2100 m, using reclass module in IDRISI32. The classified. DEM was then used to determine distribution of biomass along altitudinal gradient.

Digitization of Stock Map

The stock map available with the State Forest Department was used to derive information on land uses, forest vegetation and forest ranges. As a result of digitization, the land use coverage depicting existing six land uses as: chir pine (*Pinus roxburghii*), ban oak (*Quercus leucotricophora*), deodar (*Cedrus deodara*), other broadleaves, culturable and un-culturable (blank), forest vegetation coverage showing 538 compartments/forests and Forest Ranges coverage showing five Forest Ranges i.e., Dharampur, Parwanoo, Solan, Kandaghat and Subathu, were imported into IDRISI32.

Inventory Data

The inventory data of Solan Forest Division as a result of enumeration done in 2001 were used to generate data on tree biomass, which included name of the forest or compartment, species, number of trees in each diameter class, area of each forest in hectares and ocular density.

Estimation of Biomass

The volume of trees under each diameter classes was calculated by using local volume table. The volume was then transformed into biomass by multiplying it with specific gravity. The specific gravity was determined using maximum moisture method (Smith, 1954). However, biomass of under-storey vegetation was determined by destructive method following standard sampling technique with 1 x 1m quadrate size for shrub species. The below ground biomass of trees (root) was ascertained manually. The fallen trees (three in number) of chir pine as a result of landslide in the study area were weighed separately for root and stem after cleaning with water. The shoot and root sample of the trees were oven dried 65 ± 5°C to a constant weight and weighed for further calculations of tree biomass (Woomer, 1999). The root:stem weight ratio was then taken as standard to determine the root biomass of the entire forest assuming that all tree species bears the same root:stem weight ratio as chir pine.

Biomass of crops under culturable land use and herbaceous and shrub vegetations under un-culturable land use was estimated by laying down 1 x 1m quadrates. Shoot biomass of all the crop plants in each quadrate was harvested at ground level, and root biomass was sampled using 25 x 25 x 40 cm monolith. The monoliths were washed with a fine jet of water on 2.0 and 0.5 mm mesh screens. The shoot and root samples were oven dried at 65 ± 5°C to a constant weight and weighed for further calculations.

RESULTS AND DISCUSSION

The biomass production has been categorized in to above ground, below ground and total biomass. The biomass production in various forest ranges, land uses and altitudinal classes is presented in table 1, 2 and 3, respectively and it can be seen that the above ground biomass was higher than below ground biomass. Higher above ground biomass have been reported by various workers from time to time (Tandon *et al.*, 1988, Puri *et al.*, 1994, Singh and Mishra, 1995 and Lodhiyal *et al.*, 1995).

Biomass Distribution in Forest Ranges

Vast variation in distribution of biomass in various Forest Ranges was observed (Table 1). The maximum above ground biomass production was reported in Solan Forest Range (150.32 t ha^{-1}), followed by Kandaghat Forest Range (104.69 t h^{-1}), which is much higher than all other Forest Ranges of the Solan Division. On the other hand, the maximum below ground biomass of 47.72 t ha^{-1} was recorded in Kandaghat Forest Range, followed by Solan Forest Range (43.68 t ha^{-1}) and Dharampur Forest Range (17.62 t ha^{-1}). The minimum below ground biomass (10.10 t ha^{-1}) was recorded in the Subathu Forest Range. The maximum total biomass (194.00 t ha^{-1}) was reported in the Solan Forest Range, followed by in Kandaghat Forest Range (152.41 t ha^{-1}) and least total biomass of 44.00 t ha^{-1} in Subathu Forest Range. Higher biomass reported in Solan and Kandaghat Forest Ranges may be attributed to the dominance of ban oak at higher altitude supplemented with large amount of under growth in these forests.

Table 1. Above and below ground biomass (t) in different Forest Ranges

Forest Range	Above ground biomass (t)			Below ground biomass (Roots) (t)	Total biomass (above ground + below ground)(t)
	Stem	Under- storey	Total		
Dharampur	147862 (38.11)	124497 (31.94)	272359 (70.05)	68653 (17.62)	341012 (87.67)
Parwanoo	153884 (32.66)	83057 (17.47)	236941 (50.13)	58553 (12.36)	295494 (62.49)
Solan	147364 (102.74)	68088 (47.58)	215452 (150.32)	62611 (43.68)	278063 (194.00)
Kandaghat	60590 (77.08)	22702 (27.61)	83292 (104.69)	37814 (47.72)	121106 (152.41)
Subathu	21828 (22.14)	11741 (11.76)	33569 (33.90)	9733 (10.10)	43302 (44.00)
Total	531528	310086	841614	237364	1078978

Values in parentheses are in t ha^{-1}

Biomass Distribution in Different Land Uses

Among various land uses, the maximum above ground biomass (276.79 t ha^{-1}) was found in other broadleaves land use followed by ban oak (185.51 t ha^{-1}) and minimum values for above ground biomass was recorded in culturable land use (5.64 t ha^{-1}) (Table 2). The maximum below ground biomass production was recorded in other broadleaves land use (70.56 t ha^{-1}) followed by ban oak land use (51.70 t ha^{-1}), whereas, lowest below ground biomass was recorded in the culturable land use (2.04 t ha^{-1}). Total standing biomass in different land uses (Table 2) showed the same variations among various land uses as that for above and below ground biomass production. The maximum total biomass in other broadleaves land use (347.35 t ha^{-1}) was due to the presence of old growth of broadleaved species i.e., khair (*Acacia catechu*), walnut (*Juglans regia*), khirak (*Celtis australis*) poplars (*Populus* sp), bamboo (*Dendrocalamus* sp), etc., throughout the Solan Forest Division, whereas, minimum total biomass in culturable and un-culturable land use was obvious because of presence of low biomass yielding agricultural crops in the former and herbaceous and shrub vegetation in the later. On the other hand, lower total biomass in chir pine land use may be explained in the light of higher proportion of young age classes and sporadic distribution of Deodar in the division.

Biomass Distribution in Different Altitudinal Classes

As far the distribution of biomass in altitudinal gradient is concerned, the biomass was found to be influenced by the altitudinal variations in the region (Table 3). Above ground increased with increase in elevation. The maximum above ground biomass was exhibited by 1800-2100 m elevation (212.67 t ha^{-1}), which was much higher than 1500-1800 m (128.38 t ha^{-1}) and 1200-1500 m elevation (57.15 t ha^{-1}). Whereas, the minimum above ground biomass was reported at 900-1200 m elevation (12.16 t ha^{-1}).

A similar trend was seen for below ground biomass distribution along altitudinal classes with maximum of 54.96 t ha^{-1} at an elevation of 1800-2100 m and minimum of 2.48 t ha^{-1} at an elevation of 900-1200 m. Consequently, the above trend of above and below ground biomass distribution resulted in increase in total biomass from 14.65 t ha^{-1} to 267.64 t ha^{-1} with increase in elevation from 900 to 2100 m (Table 3). The results are in line with the findings of Awasthi *et al.* (2003) who reported low standing biomass of 140.68 $\pm$ 26.91 t ha^{-1} at low altitudes and higher biomass 477.46 t ha^{-1} at higher altitudes. The variation in the biomass level at different altitude can be explained on the basis of wood species and soil organic carbon. Lower biomass production at lower elevation was due to the presence of low wood density species at elevation from 900-1200m followed by chir pine at 1200-

Table 2. Above and below ground biomass (t) under different land uses

Land use	Above ground biomass (t)			Below ground biomass (Root) (t)	Total biomass (Above ground and below ground)(t)
	Stem	Under- storey	Total		
Chir pine	137880 (53.52)	164902 (64.01)	302782 (117.53)	92528 (35.91)	395310 (153.45)
Ban oak	205190 (137.61)	71417 (47.89)	276607 (185.51)	77091 (51.70)	353698 (237.22)
Deodar	6234 (95.90)	3284 (50.52)	9518 (146.43)	2908 (44.75)	12426 (191.16)
Other broadleaves	182224 (202.69)	66615 (74.09)	248839 (276.79)	63437 (70.56)	312276 (347.35)
Culturable	-	3868 (5.64)	3868 (5.64)	1400 (2.04)	5268 (7.69)
Total	531528	310086	841614	237364	1078978

Values in parentheses are in t ha^{-1}

Table 3. Above and below ground biomass (t) in different altitudinal classes

Elevation(m)	Above ground biomass (t)			Below ground biomass (Roots) (t)	Total biomass (Above ground + below ground) (t)
	Stem	Under- storey	Total		
900-1200	4046 (2.32)	17133 (9.84)	21179 (12.16)	4328 (2.48)	25507 (14.65)
1200-1500	195684 (31.38)	160023 (25.77)	355707 (57.15)	101574 (16.29)	457281 (73.45)
1500-1800	263074 (89.26)	113268 (39.11)	376342 (128.38)	108100 (36.68)	484442 (165.06)
1800-2100	68726 (161.70)	19662 (50.96)	88388 (212.67)	23362 (54.96)	111750 (267.64)
Total	531528	310086	841614	237364	1078978

Values in parentheses are in t ha^{-1}

1500m, which has wood density of 0.465. However, at higher elevation, the deodar and ban oak were dominating species (1800-2100m), which have comparatively higher wood density of 0.468 and 0.85, respectively. Therefore, it can be concluded that as we move from lower to higher elevation the proportion of the tree species having higher wood density increased and hence biomass. Additionally, more level of organic carbon at higher elevation may have favoured higher biomass production. Similar views have been expressed by Lehmann *et al.* (1998) and Rao *et al.* (1997).

The study revealed that the Dharampur Forest Range accounted for 31.60%, Parwanoo 27.38%, Solan 25.77%, Kandaghat 11.22% and Subathu 4.01% of total biomass (1.07 M t). However, on hectare basis, maximum was in Solan Forest Range (194.00 t ha^{-1}), which was 4.40, 3.10, 2.21 and 1.27 times higher than Subathu, Parwanoo, Dharampur and Kandaghat Forest Range, respectively. The inference can therefore be drawn that plantations of especially broad leaved species may be extended to the barren areas in the lower elevations so as to exploit the carbon sequestration potential of Solan Forest Division.

The chir pine land use contributes 36.63%, ban oak 32.78%, other broadleaves 28.94%, deodar 1.15% and culturable landuse 0.48% to total biomass of 1.07 M t in the Solan Forest Division. However, on hectare basis, it was maximum in other broadleaves (347.35 ha^{-1}), which was 45.16, 2.26, 1.81 and 1.46 times higher than culturable, chir pine, deodar and ban oak land use, respectively. However, 44.89% biomass was found distributed in 1500-1800 m, 42.38% in 1200-1500 m, 10.35% in 1800-2100 m and 2.36% in 900-1200 m elevation. On per hectare basis, the biomass increased with increase in elevation. Maximum total biomass recorded at elevation 1800-2100 m (267.64 t ha^{-1}) was 18.26, 3.64 and 1.62 times higher than 900-1200m, 1200-1500 m and 1500-1800 m elevation, respectively.

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