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Vegetation Structure, Biomass and Carbon Content in *Pinus roxburghii* Sarg. Dominant Forests of Kumaun Himalaya

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Abstract

Present study deals with vegetation structure, biomass and carbon content of pine (*Pinus roxburghii* Sarg.) dominated forests in Nainital district of Kumaun in Uttarakhand. Tree density and basal area ranged from 1040-1260 individual /ha and 36.26-56.40 m^2/ha respectively in the studied forest sites. Biomass and carbon was 154-301 t/ha and 73-143 t/ha respectively. Of this, pine shared 86.29, 90.70, 80.0 and 81.3 percent Density, basal area, biomass and carbon of pine tree accounted for about 86, 91, 80 and 81 percent respectively of the total forest vegetation. In forest site-1, the tree density, basal area, biomass and carbon content were on the lower side than forest site-2 and site-3. It was due to greater anthropogenic pressure, frequent landslips and soil erosion. Therefore it is concluded that site needs more conservation inputs to prevent the disturbances.

Introduction

Forests in the region of Uttarakhand are mainly composed of three dominated tree species such as Sal (*Shorea robusta* Gaertn.) in lower elevation (400-1200m), pine (*Pinus roxburghii* Sarg.) in mid elevation(1200-1800m) and Oak (*Quercus* spp.) in higher elevation(1400-2700m), which indicates that the forest tree composition changes with the change in altitude and climate in the region. Forests in the region have been managed either by the foresters and villagers depending on their ownerships. Uttarakhand has 64.79% and 45.82 forest area and forest cover (FSI, 2013), of this, about 80 percent forests are under the management control of forest department and a very small forest area (<20%) are managed by villagers for their basic needs. Forest growing anywhere plays a vital role in the supply of raw materials to the various sectors and in conserving the environment (Lodhiyal, 2011).

Chir-pine forests are 14,356 km^2 (55.4%) of the total conifers (25,934 km^2) in the country. While the total area of pine forest in Uttarakhand is about 3.43 lakh hectares and produces about 20.58 lakhs tones of dry pine needle biomass annually. The pine needles are used for fuel coal for cooking purpose and dry needles are also used for cattle bedding in the villages of the region. One estimate had shown that the pine needles if collected from the pine forests near to habitation and or near to road head it is assumed that about 40% of needle biomass can be transported from such sites for different uses. Chir pine forest occurs extensively in the low to mid mountain belt of central and western Himalaya. On northern aspect pure chir-pine forest occurs mainly at elevations of 900-1500m but on southern aspects the limits are about 300m.

Chir-pine forests in the region generally found as a pure forest but sometimes other tree species is also associated with chir-pine forests such as *Rhododendron arboreum*, *Myrica esculenta*, *Quercus* spp., *Pyrus pasia*, *Cupressus torulosa* and *Sapium insigne* while these tree species share are very less in the region. So the major contribution was made by *Pinus roxburghii* tree species in the region. Thus the biomass and carbon in vegetation are considered important components as these play a significant role for meeting the needs of people and industries as well as in combating the climate change problems of the region. Among the various dominated tree species in the region, Pine (*Pinus roxburghii*) is one of the major forests forming species. Present paper deals with vegetation structure, biomass and carbon content of pine (*Pinus roxburghii* Sarg.) forests in the district Nainital of Kumaun region of Uttarakhand. Biomass and carbon of tree species play a significant role in mitigating climate change. Carbon shares nearly 45-50 percent of tree biomass but it depends on the tree species characteristics and growing locality. Chir-pine forest is a gregarious, fire resistance and indigenous tree species often forming pure forests (Champion and Seth, 1968).

Biomass of forests when analysed properly provides the real picture of growing stock in a site but it varies from site to site within the ecological zone as well as presence of tree species whether they are evergreen and deciduous. It also influences by the management inputs given by foresters. However, there were a lot of study has been carried out in the past by many researchers in the region and elsewhere but exact information on carbon issues has not been available till date. Therefore it is very imperative and growing requirements to know the proper findings of dry matter issues and carbon content due to recent climate change and its influences on the forest structure and function particularly in the Himalayan region. Keeping in view, assessing the dry matter and carbon in the pine forest at three sites in the context of climate change provide important preliminary information was done in three sites of pine forest sites in Nainital forest division of Kumaun Himalaya in Uttarakhand.

Materials and methods

Description of study site: Present forest sites were located in Khurpatal in between 29^{0}58' N latitude and 79^{0}28' E longitude located within the elevation ranges 1450 from 1800m in Nainital district. Soil in this study area was varies from site to site as there were many area where the site having certain amount of soils with boulders. The pine forests generally grow in rocky soils where other tree species mostly does not found. The climate of the pine forests sites generally warm and humid therefore certain plant communities that tolerate the high temperature occurs in the under canopy of pine.

Vegetational Analysis: The tree analysis was done by placing random quadrates of 10 x10m size in each forest site. In each quadrat, all the tree species were measured at 1.37m (circumference at breast height) from ground level. The tree density, abundance and basal area and IVI of trees were estimated in each forest site as followed by (Misra, 1968; Saxena and Singh, 1982; Curtis & McIntosh, 1950; Phillips, 1959).

Biomass Estimation: The biomass of forest tree species was estimated by using allometric equations as developed by (Chaturvedi and Singh, 1987; Lodhiyal *et al*; 2014). The total biomass determine by summing up the respective component values of each tree species occurred in each in each site. The regression equation was used in the form y=a+b Inx, where y=dry weight of component (kg), x=GBH (cm), a=intercept, b= slope or regression coefficient and ln=log natural.

Carbon estimation: Carbon was estimated using the method as given by (Magnussen and Reed, 2004; Singh and Lodhiyal, 2009). The total carbon was estimated by summing up of carbon values of all tree components in each forest.

Results and Discussion

Vegetation structure: The total three species were present i.e. *Pinus roxburghii*, *Cupressus torulosa and Sapium insigne* in this forest site. The total tree density was 1040 ind/ ha, of which, chir-pine accounted for 81 percent. The basal area and IVI of forest was 56.4 m^2/ha and 299.9. Of this, basal area and IVI of chir-pine shared 50.4 m^2/ha and 212.9 respectively at forest site 1 (Table 1).

Table 1: Vegetation analysis of trees in chi-pine forest in site-1

Species Composition	Density ind/ha	Frequency (%)	Abundance	A/F Ratio	TBA (m^2/ha)	IVI
Pinus roxburghii	840	90	9.33	0.104	50.4	212.99
Cupressus torulosa	130	70	1.86	0.027	3.9	52.75
Sapium insigne	70	50	1.40	0.028	2.1	34.25
Total	1040	210	12.59	0.158	56.4	299.99

Note: TBA= Total Basal Area, IVI= Important Value Index

The three species i.e. *Pinus roxburghii*, *Cupressus torulosa* and *Sapium insigne* were present in this forest site. The density of forest was 1200 ind/ha of this, Chir-pine (*Pinus roxburghii*) accounted for 82.5% density. Total basal area of chir-pine forest was 48.9 m^2/ha. Of this, basal area and IVI of *Pinus roxburghii was* 43.6 m^2/ha *and* 214.9 respectively at forest site 2 (Table 2).

Table 2: Vegetation analysis of trees in Chir-pine forest in site-2.

Species Composition	Density Ind/ ha	Frequency (%)	Abundance	A/F Ratio	TBA (m^2/ha)	IVI
Pinus roxburghii	990	100	9.90	0.099	43.56	214.91
Cupressus torulosa	100	60	1.67	0.028	4.10	42.79
Sapium insigne	110	70	1.57	0.022	1.32	42.30
Total	1200	230	13.14	0.149	48.98	300

Note: TBA= Total Basal Area, IVI= Important Value Index

Total two trees species viz., *Pinus roxburghii* and *Sapium insigne* were occurred in this forest site. The total density of forest was 1260 ind/ha. Of this, *Pinus roxburghii* accounted for 94.4 percent. The total basal area of forest was 36.3 m^2/ha. Of this, chir-pine trees shared 34.5 m^2/ha basal area and 261.0 IVI at forest site 3(Table 3).

Table 3: Vegetation analyses of trees in chi-pine forest in site-3

Species Composition	Density ind/ha	Frequency (%)	Abundance	A/F Ratio	TBA (m^2/ha)	IVI
Pinus roxburghii	1190	100	11.90	0.119	34.51	261.04
Sapium insigne	70	40	1.75	0.044	1.75	38.95
Total	1260	140	13.65	0.163	36.26	299.99

Note: TBA= Total Basal Area, IVI= Important Value Index

Biomass: The total forest biomass was 301.1t/ha of this, *Pinus roxburghii* accounted for 80 percent in forest site-1. The bole component biomass was 57.6% while stump root biomass accounted for 14.0 % (Table 4).

Table 4: Component-wise biomass (t/ha) of chir-pine forest in site-1 (value in parenthesis is percent contribution).

Name of Tree Species	Bole	Bole bark	Branch	First order branch	Other branch	Twig	Foliage	Cone	Stump root	Lateral root	Fine root	Total
Pinus roxburghii	151.06 (62.53)	-	-	27.16 (11.24)	9.40 (3.89)	-	8.01 (3.32)	0.81 (0.34)	34.66 (14.35)	9.51 (3.94)	0.97 (0.40)	241.58 (80.24)
Cupressus torulosa	12.74 (36.37)	0.78 (2.22)	8.35 (23.85)	-	-	2.93 (8.37)	2.58 (7.38)	-	3.90 (11.14)	3.09 (8.83)	0.64 (1.84)	35.02 (11.63)
Sapium insigne	9.75 (39.89)	-	6.25 (25.56)	-	-	2.77 (11.31)	1.61 (6.57)	-	3.65 (14.94)	0.39 (1.58)	0.03 (0.14)	24.46 (8.12)
Total	173.55 (57.65)	0.78 (0.26)	14.60 (4.85)	27.16 (9.02)	9.40 (3.12)	5.70 (1.89)	12.20 (4.05)	0.81 (0.27)	42.22 (14.02)	12.99 (4.31)	1.64 (0.55)	301.06 (100)

Total biomass of tree species was 247.9 t/ha. of the total biomass, *Pinus roxburghii* accounted for 76.7%. Among the various tree components, biomass of bole component shared 57.0% while stump root contributed 14.4% at forest site-2 (Table 5).

Table 5: Component-wise biomass (t/ha) of Chir-pine in forest site-2 (value in parenthesis is percent contribution).

Name of Tree Species	Bole	Bole bark	Branch	First order branch	Other branch	Twig	Foliage	Cone	Stump root	Lateral root	Fine root	Total
Pinus roxburghii	118.74 (62.41)	-	-	20.11 (10.57)	7.36 (3.87)	-	7.05 (3.71)	0.80 (0.42)	27.88 (14.65)	7.48 (3.93)	0.83 (0.44)	190.25 (76.75)
Cupressus torulosa	13.61 (40.59)	0.75 (2.23)	7.78 (23.21)	-	-	2.44 (7.28)	2.20 (6.56)	-	3.70 (11.04)	2.50 (7.46)	0.55 (1.64)	33.52 (13.52)
Sapium insigne	8.99 (37.28)	-	5.97 (24.76)	-	-	2.96 (12.26)	1.71 (7.09)	-	4.03 (16.70)	0.42 (1.74)	0.04 (0.18)	24.11 (9.73)
Total	141.33 (57.02)	0.75 (0.30)	13.75 (5.55)	20.11 (8.11)	7.36 (2.97)	5.39 (2.18)	10.96 (4.42)	0.80 (0.32)	35.60 (14.36)	10.40 (4.20)	1.42 (0.57)	247.88 (100)

Total biomass of tree species was 153.9 t/ha of this *Pinus roxburghii* accounted for 130.7 t/ha. Of this, bole component shared 58.7% in the aboveground while stump root contributed 15.1% in belowground part at forest site 3 (Table 6).

Table 6: Component-wise biomass (t/ha) of Chir-pine in forest site-3 (value in parenthesis is percent contribution).

Name of tree Species	Bole	Branch	First order branch	Other branch	Twig	Foliage	Cone	Stump root	Lateral root	Fine root	Total
Pinus roxburghii	81.21 (62.12)	-	12.66 (9.69)	5.00 (3.82)	-	5.64 (4.31)	0.76 (0.58)	19.71 (15.07)	5.13 (3.92)	0.63 (0.48)	130.73 (84.94)
Sapium insigne	9.18 (39.59)	5.90 (25.47)	-	-	2.65 (11.42)	1.54 (6.63)	-	3.51 (15.14)	0.37 (1.60)	0.03 (0.14)	23.18 (15.06)
Total	90.38 (58.72)	5.90 (3.84)	12.66 (8.23)	5.00 (3.25)	2.65 (1.72)	7.18 (4.66)	0.76 (0.49)	23.22 (15.08)	5.50 (3.57)	0.66 (0.43)	153.92 (100)

Carbon content: The total carbon content of forest was 143 t/ha. Of this, *Pinus roxburghii* accounted for 114.7 t/ha. Of the total biomass bole component shared 57.6% followed by first order branch in the aboveground biomass while the stump root contributed 14.0% in followed by lateral roots (9.0%) in belowground part, while the fine roots accounted for about 1% at forest site 1 (Table 7).

Table 7: Component-wise carbon content (t/ha) of chir-pine forest site-1 (value in parenthesis is percent contribution).

Name of Tree Species	Bole	Bole bark	Branch	First order branch	Other branch	Twig	Foliage	Cone	Stump root	Lateral root	Fine root	Total
Pinus roxburghii	71.75 (62.53)	-	-	12.90 (11.24)	4.46 (3.89)	-	3.81 (3.32)	0.39 (0.34)	16.46 (14.35)	4.52 (3.94)	0.46 (0.40)	114.7 (80.24)
Cupressus torulosa	6.05 (36.37)	0.37 (2.22)	3.97 (23.85)	-	-	1.39 (8.37)	1.23 (7.38)	-	1.85 (11.14)	1.47 (8.83)	0.31 (1.84)	11.63 (8.13)
Sapium insigne	4.63 (39.90)	-	2.97 (25.57)	-	-	1.31 (11.32)	0.76 (6.54)	-	1.74 (14.95)	0.18 (1.58)	0.02 (0.14)	11.61 (8.12)
Total	82.44 (57.65)	0.37 (0.26)	6.94 (4.85)	12.90 (9.02)	4.46 (3.12)	2.71 (1.89)	5.79 (4.05)	0.39 (0.27)	20.05 (14.02)	6.17 (4.31)	0.78 (0.55)	143 (100)

The total carbon in forest site-2 was 117.7 t/ha. Of this, *Pinus roxburghii* accounted for 90.4 t/ha. Of the total carbon, bole wood component accounted for 57 percent followed by first order branch followed by 8.1 % in the aboveground while stump root contributed 14.4% in belowground part at forest site 2 (Table 8).

Table 8: Component wise carbon content (t/ha) in each tree species in forest Site-2 (value in parenthesis is percent contribution).

Name of Tree Species	Bole	Bole bark	Branch	First order branch	Other branch	Twig	Foliage	Cone	Stump root	Lateral root	Fine root	Total
Pinus roxburghii	56.40 (62.41)	-	-	9.55 (10.57)	3.49 (3.87)	-	3.35 (3.71)	0.38 (0.42)	13.24 (14.65)	3.56 (3.93)	0.40 (0.44)	90.37 (76.75)
Cupressus torulosa	6.462 (40.59)	0.35 (2.23)	3.70 (23.21)	-	--	1.16 (7.28)	1.05 (6.56)	-	1.76 (11.04)	1.19 (7.46)	0.26 (1.64)	15.92 (13.52)
Sapium insigne	4.27 (37.28)	-	2.84 (24.76)	-	-	1.40 (12.26)	0.81 (7.09)	-	1.91 (16.70)	0.20 (1.74)	0.02 (0.18)	11.45 (9.73)
Total	67.13 (57.02)	0.35 (0.30)	6.53 (5.55)	9.55 (8.11)	3.49 (2.97)	2.56 (2.18)	5.20 (4.42)	0.38 (0.32)	16.91 (14.36)	4.94 (4.20)	0.68 (0.57)	117.74 (100)

The carbon content of forest was 73.1t/ha. Of this, *Pinus roxburghii* accounted for 62.1t/ha. Among the components, carbon content in bole wood accounted for 58.7% in the aboveground while stump root contributed 15.1% in belowground part at forest site 3 (Table 9).

Table 9: Component wise carbon content (t/ha) in each tree species in forest Site-3 (value in parenthesis is percent contribution).

Name of Tree Species	Bole	Bole bark	Branch	First order branch	Other branch	Twig	Foliage	Cone	Stump root	Lateral root	Fine root	Total
Pinus roxburghii	38.57 (62.12)	-	6.01 (9.69)	2.37 (3.82)	-	2.68 (4.31)	0.36 (0.58)	9.36 (15.07)	2.44 (3.92)	0.30 (0.48)	62.10 (84.94)	38.57 (62.12)
Cupressus torulosa	4.36 (39.59)	2.80 (25.47)	-	-	1.26 (11.42)	0.73 (6.63)	-	1.67 (15.14)	0.18 (1.60)	0.02 (0.14)	11.01 (15.06)	4.36 (39.59)
Sapium insigne	42.93 (58.72)	2.80 (3.84)	6.01 (8.23)	2.37 (3.25)	1.26 (1.72)	3.41 (4.66)	0.36 (0.49)	11.03 (15.08)	2.61 (3.57)	0.32 (0.43)	73.11 (100)	42.93 (58.72)
Total	38.57 (62.12)	-	6.01 (9.69)	2.37 (3.82)	-	2.68 (4.31)	0.36 (0.58)	9.36 (15.07)	2.44 (3.92)	0.30 (0.48)	62.10 (84.94)	38.57 (62.12)

Forest plays a significance role in the development, livelihood and climate they provide timber, non-timber products agricultural implements to hill people and also improve fertility of the agriculture soil and control erosion and forests composition in the hill region, vary from place to place because of altitude, climate, slope, aspect and soil characteristics. The objectives of study were to assess the vegetation structure (density, frequency, abundance, basal area and IVI), biomass and carbon content in pine forests. The density ranged from 1040 to 1260 ind/ha in the tree-studied forests. Present values fall within the range 920-1345 ind./ha reported for natural forests of Lohaghat (Lodhiyal et al., 2014) and 540-1630 ind/ha for pine forests in Kumaun region (Chaturvedi Singh, 1987). The basal area (36.3-56.4 m^2/ha) was on the lower side than 58.66-93.00 m^2/ha reported for natural forests (Lodhiyal et al., 2014) and higher side than 25-47m^2/ha reported for pine forests in Kumaun region (Chaturvedi and Singh, 1987). The total biomass of chir pine forests was 154-301t/hawhich on the lower side than 651- 718 t/ha reported for tree biomass natural forests (Lodhiyal *et al*., 2014) 112-283t/ha reported for pine forests of central Himalaya (Chaturvedi and Singh 1986) and 199 t/ha for chir pine forest (Rana *et al.,* 1989). Of the total biomass, *Pinus roxburghii* accounted for 242, 190 and 131t/ha respectevely for site -1, 2 and 3 (Table 4 -7). The carbon content ranged from 73-143 t/ha on lower side than 341-228 t/ha reported for natural forests (Lodhiyal *et al*., 2014), 97-207 t/ha reported for pine and mix Banj-oak forests (Rana *et al.,*1989) and 122-86 t/ha for chir- pine van Panchayat forest (Jeena *et al.,*2008). *Pinus roxburghii* accounted for 115.0, 90.0 and 62.0 t/ha carbon content in forest site-1, 2 and 3 respectively of the total carbon estimates. Present values of density, basal area, tree species composition, biomass and carbon, it is concluded that there is an urgent need of conservation and management of present studied forests so that vegetation structure, species composition, biomass and carbon content of forests could be improved.

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