

Carbon Sequestration Potential of Chir Pine (*Pinus roxburghii*. Sarg) Forest on Two Contrasting Aspects in Kumaun Central Himalaya between 1650-1860 m Elevation

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Abstract The tree density for Chir Pine forests on the southern aspect was 1676.66 indi./ha and on northern aspect 1026.66 indi./ha. The tree biomass on southern aspect was 252.65 t ha⁻¹ and on northern aspect it was 453.58 t ha⁻¹. The tree biomass accumulation rate on the southern aspect was lower than the northern aspect. The forest carbon stock on the southern aspect was 120.0 t ha⁻¹ compared to 215.45 t ha⁻¹ on the northern aspect. The carbon sequestration rate on the northern aspect was also lower than southern aspect.

Keywords: aspect, biomass, girth-class, tree density

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1. Introduction

Trees remove carbon dioxide from the atmosphere through the natural process of photosynthesis and store the carbon (C) in their leaves, branches, stems, bark and roots. Approximately half the dry weight of a tree's biomass is carbon. Natural and planted forests act as 'sinks' for absorbing CO₂ from the atmosphere. Increasing the area of forests and tree plantations is one method available to 'offset' emissions of CO₂ [1].

According to UNFCCC (2010) [2] the process of removing carbon from the atmosphere and depositing it in a reservoir is Carbon sequestration. Carbon sequestration potential of a forest determines its capacity as a sink for sequestering atmospheric carbon as stand biomass. In the global context the terrestrial forests ecosystems constitute 54% of the 2,200 Gt of the total carbon pool. Tree growth serves as an important means to capture and store atmospheric carbon dioxide in vegetation, soils and biomass products [3]. Expanding the size of the global terrestrial sink is one strategy for mitigation of atmospheric carbon dioxide build up. Currently, the total aboveground biomass in the world's forests (421 x 10⁶ tonnes) is distributed over a total area of 3869 million hectare; 95% of this is in natural forest and 5% in plantation forest and estimates of the net carbon uptake of forests range from 1 to 4 t ha⁻¹ per year for tropical rain forest and temperate deciduous forest, respectively [4,5]. However, considerable variation exists between forests, and between similar forests at different latitudes [6,7,8,9].

The carbon pools continue to increase over the life cycle of a forest towards a state of equilibrium when respirational CO₂ losses by plants and soils and decomposition of biomass equals rate of growth [10,11]. The specific girth class category of trees plays a significant role in the estimation of tree biomass and carbon of a forest as the trees which are greater in diameter (mature trees) tend to accumulate more biomass than the trees which have less diameter (Young trees). Almost 74% of the total aboveground carbon was sequestered in woody biomass of trees with diameter between 20 to 49.99 cm and the rate of sequestration was higher in trees of diameter classes (20-29.99) cm and (10-19.99) cm with values 0.95 tons/ha/year and 0.62 tons/ha/year respectively; accounting 71% of the annual sequestration rate of the forest [12] and above ground biomass was greater in the 40-60 cm diameter class in plantation forest and in 60-80 cm dbh class in natural forest [13].

2. Materials and Methods

The two study sites were located in the Nainital district of Kumaun Central Himalayas between the 29.24° N to 30.35° N and 79.27° E to 79.37° E respectively. The study sites were different in aspects and altitudes. The Khurpatal forest site is located on southern aspect at an altitude of 1650 meter and the Kahalqueera forest site is located on northern aspect at an altitude of 1860 meter.

The study was conducted during 2009-2010 after the establishment of 10 permanent plots of 10 x 10 meters on

each aspect. The trees were categorized into different girth classes according to CBH (circumference at breast height) as 0-10 cm- A, 11-17.5 cm- B, 18-63.5 cm- C, 64-110 cm- D, 111-160 cm- E, 161-210 cm- F, 211-260 cm- G, >-260 cm- H. The vegetational analysis was conducted in both the aspects [14].

Table 1.1. Site description for the studied sites.

Serial No.	Site	Aspect	Altitude (meters/asl)	Species
1.	Khurpatal	Southern	1650	<i>Pines roxburghii</i>
2.	Kahalqueera	Northern	1860	<i>Pinus roxburghii</i>

The biomass accumulation for the trees was studied following previously developed allometric relationships for Chir-Pine forests [15] and the carbon accumulation for the trees was estimated [16,17,18].

3. Results

Total tree density on the southern aspect was 1676.66 indi./ha and total tree biomass of the site was 246.11 t ha⁻¹ in first year which increased to 252.65 t ha⁻¹ in second year with mean biomass increment of 6.54 t ha⁻¹. Maximum above-ground biomass was contributed by mature trees of girth class E (111-160 cm) which was

82.37% and maximum below-ground biomass was contributed by mature trees of girth class D (64-110 cm) which was 18.78%. Minimum above-ground and below-ground biomass was contributed by young trees of girth class B (11.17.5 cm) which was 52.48% and 7.023% respectively. Total forest carbon on this site was 116.90 t ha⁻¹ in first year which increased to 120.0 t ha⁻¹ in second year with the carbon sequestration rate of 3.1 t ha⁻¹ yr⁻¹, while highest carbon sequestration rate was recorded in girth class C (18-63.5 cm) on this aspect.

Total tree density for the northern aspect was 1026.66 indi./ha and total biomass of this site was 440.81 t ha⁻¹ in first year which increased to 453.58 t ha⁻¹ in second year with mean biomass increment of 12.76 t ha⁻¹. Maximum above-ground biomass was contributed by mature trees of girth class E (111-160 cm) which was 82.27% and maximum below-ground biomass was contributed by mature trees of girth class D (64-110 cm) which was 18.63%. Minimum above-ground and below-ground biomass was contributed by young trees of girth class B (11.17.5 cm) which was 26.22 % and 7.11% respectively. Total forest carbon on this site was 209.38 t ha⁻¹ in first year which increased to 215.45 t ha⁻¹ in second year with the carbon sequestration rate of 6.07 t ha⁻¹yr⁻¹, while highest carbon sequestration rate was recorded in girth class F (161-210 cm) on this aspect.

Table 1.2. Vegetational Parameters of studied sites

Site	Density (indi./ha)	Biomass (t/ha ⁻¹)		Biomass increment (t/ha ⁻¹ yr ⁻¹)	Carbon (t/ha ⁻¹)		Carbon sequestration rate (t/ha ⁻¹ yr ⁻¹)
		Year 1	Year 2		Year 1	Year 2	
Khurpatal	1676.66	246.11	252.65	6.54	116.90	120.0	3.1
Kahalqueera	1026.66	440.81	453.58	12.76	209.38	215.45	6.07

Table 1.3. Biomass and carbon sequestration rates in above and below ground biomass values of Southern and Northern Aspects in different girth classes of Chir-Pine forest (Girth classes are 0-10 cm- A, 11-17.5 cm- B, 18-63.5 cm- C, 64-110 cm- D, 111-160 cm- E, 161-210 cm- F, 211-260 cm- G, >-260 cm- H)

Site	Girth Class	Biomass (t/ha ⁻¹)		Biomass increment (t/ha ⁻¹ yr ⁻¹)	Carbon (t/ha ⁻¹)		Carbon Sequestration rates (t/ha ⁻¹ yr ⁻¹)
		Y ₁	Y ₂		Y ₁	Y ₂	
Khurpatal	A	0.25	0.35	0.1	0.118	0.166	0.04
	B	1.48	1.484	0.004	0.703	0.705	0.002
	C	25.93	28.409	2.479	12.32	13.49	1.174
	D	23.6	25.57	1.97	11.21	12.05	0.84
	E	90.32	90.96	0.64	42.90	43.20	0.3
	F	38.95	40.25	1.3	18.50	19.12	0.62
	G	65.58	65.93	0.35	31.15	31.32	0.17
	H	-	-	-	-	-	-
		246.11	252.65		116.90	120.0	
Kahalqueera	A	-	-	-	-	-	-
	B	0.3	0.314	0.014	0.142	0.149	0.007
	C	12.03	13.11	1.08	5.714	6.227	0.513
	D	54.23	55.29	1.06	25.75	26.26	0.51
	E	183.93	187.22	3.29	87.36	88.92	1.56
	F	117.91	125.24	7.33	56.00	59.48	3.48
	G	-	-	-	-	-	-
	H	72.408	72.409	0.001	34.39	34.394	0.004
	Total	440.81	453.58		209.38	215.45	

4. Discussion

In the present study we have tried to estimate the biomass and carbon sequestration values in the Chir-Pine (*Pinus roxburghii*) forest in the different girth classes on two contrasting aspects.

The results shows that on both southern and northern aspects the E (111-160 cm) and D (64-110 cm) girth classes which were mature trees, had maximum above and

below ground biomass contribution and B (11-17.5 cm) girth class had minimum above and below ground biomass contribution. The northern aspect had higher biomass and carbon sequestration rate than the southern aspect (Figure 1) even when the tree density was lower than southern aspect, which is due to presence of mature trees. The mature trees on the northern aspect had higher biomass accumulation rate.

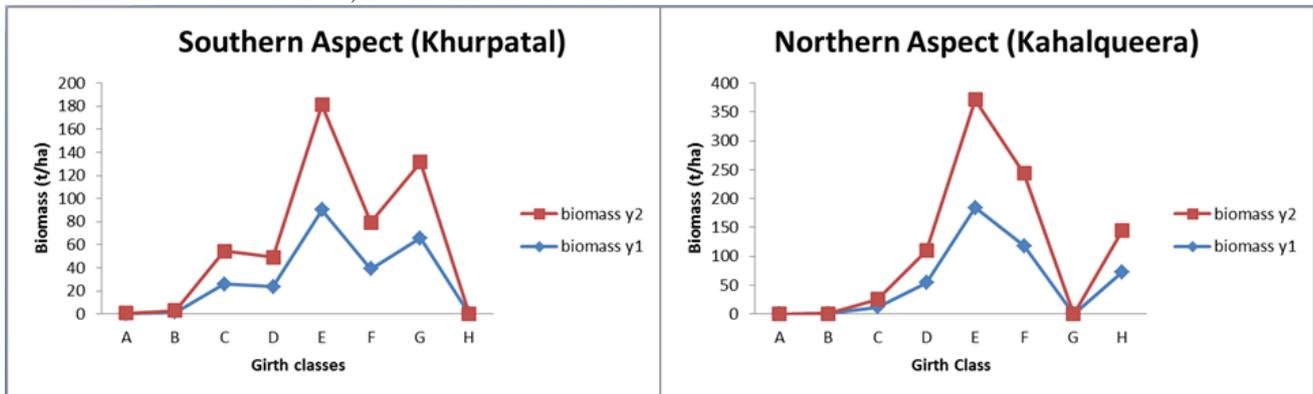


Figure 1. Showing variation in above and below ground biomass values of Southern and Northern Aspects in different girth classes of Chir-Pine forest (Girth classes are 0-10 cm- A, 11-17.5 cm- B, 18-63.5 cm- C, 64-110 cm- D, 111-160 cm- E, 161-210 cm- F, 211-260 cm- G, >260 cm- H)

The estimated tree density values in present study were 1676.66 for southern aspect and 1026.66 for northern aspect, were similar to [19] which reported the tree density for Chir-Pine forest was between 540-1630 trees/ha in the central Himalayas of India. Similarly, tree density of 672/ha in a young forest of Chir-Pine in Toli Van Panchyat, India was also reported [20]. Total carbon stock of 81.31 - 115.40 tons/ha with sequestration rate 5.06 - 6.66 tons/ha/yr in non-degraded forest whereas the total carbon stock of 17.49 - 33.42 tons/ha with carbon sequestration rate 1.07 - 1.27 tons/ha/yr in degraded sites of Chir-Pine at Kumaon, Central Himalaya of India was also reported [21].

The present study provided a similar scenario [12,13] where the higher biomass was accumulated in the mature tree of 111-160 cm girth class and 64-110 cm girth class respectively. This gives an emphasis on the conservation and protection of mature natural forests which act as a greater for carbon sequestration.

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