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Carbon Stock of *Pinus roxburghii* Sarg. in Siwalik Foot Hills of Jammu

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Abstract

The present study was carried out in the year 2021 to estimate the biomass and Carbon stock of *Pinus roxburghii*. Ten quadrates of size 20×20 m^2 were laid out randomly. Diameter at breast height (dbh) and tree height was measured as the primary data. The regression equation *VV=0.05131+3.98598D–1.0245vD* was used for determining the mean stem volume. The mean tree density, mean tree diameter, mean tree height and mean stem volume at the study site were 150 trees ha^{-1}, 51.21 cm, 19.79 m and 157.17 m^3 ha^{-1}, respectively. Similarly, above ground biomass density (AGBD), below ground biomass density (BGBD), total biomass density (TBD) and total carbon density (TCD) at the study site was 93.99 Mg ha^{-1}, 26.32 Mg ha^{-1}, 120.30 Mg ha^{-1} and 56.54 Mg ha^{-1}, respectively. Average eCO_2 was 207.51 Mg ha^{-1}. Average soil bulk density was 1.39 gm cm^{-3}, soil ph 6.47, EC 0.13, SOC 6.31 gm kg^{-1}, NPK 201.44 Mg ha^{-1}, 26.50 Mg ha^{-1} and 56.66 Mg ha^{-1}, respectively. The soils in the site were almost clay with average percent of sand, silt and clay as 32.44, 30.99 and 36.57, respectively.

Keywords: Biomass, carbon stock, breast height, quadrate, regression

1. Introduction

Carbon (C) sequestration is a long-term entrapping and storing of atmospheric C in different C sinks such as vegetation and soils (Gibbs et al., 2007). Estimation of forest C is essential to assess the structural attributes, forest productivity and C sequestration potential as well as C stock (Chave et al., 2005). Variation in forest biomass and C stocks is due to the species diversity in the forests (Bora et al., 2013). Various factors such as climatic, topographic, edaphic and biotic influences the structure and distribution of vegetation and its type, hence affecting the C stock at a particular site (Melkania, 2009). One of the important dominant tree species of the Siwalik foot hills of the Himalaya is *Pinus roxburghii*, which has the immense potential in mitigating the climate change.

Pinus roxburghii Sarg. (commonly known as Chir Pine or Himalayan long needle pine) is native to Himalaya, occurring between 450 and 2300 m above sea-level in nearly all principal valleys, where the full force of the monsoon is felt. In Himalaya, it covers wide areas as pure forests and also in mixtures with other broad-leaved and coniferous species such as *Quercus leucotrichophora*, *Rhododendron arborium*, *Lyonia ovalifolia*, *Myrica esculenta*, *Cedrus deodara* and *Pinus wallchiana* towards its upper limit and *Shorea robusta*, *Anogeissus latifolia*, *Ougeinia oojeinensis* and *Bauhinia variegata* towards the lower limit. It is a fire-resistant indigenous tree species which at higher elevations prefers hotter slopes and drier areas. In the Siwalik area it is found in groups in the form of strips in association with broad-leaved species. Certain qualities such as high regeneration potential (Kumar and Bhatt, 1990), capacity to colonise degraded habitats (Joshi, 1990), rapid growth (Misra and Lal, 1984), straight cylindrical bole and high-volume returns (Singh, 1979) and ability to yield considerable amount of resin (Deshmukh, 1966) make this species a precious resource in this region.

The Siwalik forests of Himalayas are facing severe degradation due to rapid anthropogenic activities (Upadhyay et al., 2005). Deforestation is considered as second highest green house gases emissions source quantified to release an estimated 2 Giga tons of C (GtC) yearly over the last few years (Kindermann et al., 2006). Study area was located in the Siwaliks belt of Himalayan foothills characterized by subtropical mixed forest types dominated by Chir Pine. The objective of the study was to estimate the C stocks and C sequestration potential of *Pinus roxburghii* in the Siwalik of Jammu.

2. Materials and Methods

The study was carried out in the year 2021 in the Siwalik region of Jammu in Samba district to estimate the biomass and C stock of *Pinus roxburghii* forest. The foothill of Himalayas is commonly termed as the Siwalik comprising of hilly portion

having small dry hillocks, with rugged and undulating topography. This site lies within the Bahu and Jindarh range of Jammu Forest division (some portion of which is now in the newly formed Samba Forest division). The sampling plots were laid within an altitudinal range between 500 to 900 m. The sampling area stretches from 32˚ 42.09'' N to 32˚ 46.78'' N latitude and 75˚ 00.77'' E to 75˚ 09.24'' E longitude. The mean minimum and maximum temperature for Jammu Siwalik under winter, summer and monsoon season is 4˚C, 23˚C and 18˚C, 40˚C and 14˚C, 32˚C, respectively (Goyal and Rai, 2000). The average annual rainfall is about 1140 mm per annum, out of which 70% is received during the monsoon period. Terrain is rocky and generally shallow. On gradual increase in altitude the vegetation changes from mixed broadleaved to dominant Chir Pine in the upper zone. Some common tree species found in this area were *Dalbergia sisso*, *Acacia modesta*, *Butea monosperma*, *Lannea coromendalica*, *Mallotus philippensis*, *Ficus glomerata*, *Pinus roxburghii*, *Dendrocalamus stritus*, *Bombax ceiba*, *Ficus religiosa*, *Phoenix sylvesteis*, *Cassia fistula*, *Eucalyptus teriticornis*, etc. Shrub and grasses included *Euphorbia royleana*, *Woodfordia fruiticosa*, *Adhatoda vasica*, *Dodonea viscosa*, *Murraya koenigii*, *Lantana camara*, *Parthenium hysterophorus*, *Rumex hastatus* and *Cymbopogan* spp.

Ten quadrates of size 20×20m^2 were laid out randomly. The diameter at breast height (DBH) was measured with help of tree calliper and tree height with help of forestry pro laser rangefinder. The regression equation *VV=0.05131+3.98598D–1.0245VD* (FSI, 1981) was used for determining the mean stem volume. Above ground biomass density (AGBD) was calculated by multiplying mean stem volume to wood density (0.46 gm cm^{-3}) and to a suitable biomass expansion factor. Below ground biomass density (BGBD) was calculate by multiplying AGBD to factor 0.28 (Mokany et al., 2006). Total biomass density (TBD) was obtained by adding AGBD and BGBD. Similarly, the total C density (TCD) was determined by multiplying TBD to factor 0.47. Carbon dioxide equivalent (eCO_2) was calculated by multiplying TCD to 3.67 (Siraj, 2019).

Samples for the soil analysis were collected from the soil depth of 0-30 cm. They were analysed at the Soil laboratories of the Division of Soil Science & Agricultural Chemistry, SKUAST-Jammu. Soil bulk density was determined by core tube method as prescribed by Johnson (1996), soil pH was measured with the help of pH meter and soil electrical conductivity (EC) with help of EC meter, as suggested by Jackson (1973). Method suggested by Walkley and Black (1934) was used for estimating soil organic carbon (SOC). Available nitrogen (N) was estimated by automatic Kjeldhal distillation unit following the modified alkaline potassium permanganate method as proposed by Subbiash and Asija (1956). Available phosphorus (P) was determined by the method described by Olsen et al. (1954). Available potassium (K) was estimated by Using 1N Ammonium Acetate as the extracting agent the available potassium was determine on flame photometer as suggested by Jackson, 1973.

3. Results and Discussion

Maximum Tree density (325 trees ha^{-1}) was observed at QX whereas, the minimum (75 trees ha^{-1}) was observed at QIV. Overall, the mean tree density at the site was 150 trees ha^{-1} (Table 1). Maximum (61.91 cm) tree diameter was recorded from QV and minimum (25.13 cm) from QX. Overall, the mean diameter at site was 51.21 cm (Table 1). Maximum Tree height (30.58 m) was recorded in QV whereas, the minimum (11.35 m) was recorded from QVII. Overall, the mean tree height at the sampling site was 19.79 m (Table 1). Stem volume was observed maximum (236.10 m^3 ha^{-1}) from QX and minimum (91.45 m^3 ha^{-1}) from QIV. Over all the stem volume at the site was 157.17 m^3 ha^{-1} (Table 1). Tree density at the site was low which may be due to the anthropogenic disturbances which affects the regeneration and also might be due to frequent forest fires. Mainly larger diameter trees were found scattered in the lower altitudes of the sampling site which shows poor regeneration and also the low tree height might be the sign of poor site quality. Cienciala et al. (2016) have reported significant effects of site variables such as C/N ratio, soil pH and EC, soil texture and standard precipitation index (SPI) on the growth of Norway spruce.

Table 1: Growth parameters of *Pinus roxburghii* in Siwalik hills of Jammu

Quadrate	Tree density	Mean diameter	Mean height	Stem Volume
	Trees ha^{-1}	(cm)	(m)	m^3 ha^{-1}
I	100	52.79	14.70	118.47
II	125	52.93	17.20	147.41
III	125	59.87	23.20	159.24
IV	75	55.20	18.93	91.45
V	125	61.91	30.58	162.95
VI	200	51.83	27.26	234.04
VII	150	40.61	11.35	150.32
VIII	150	59.16	18.50	124.02
IX	125	52.68	19.00	147.67
X	325	25.13	17.20	236.10
Mean	150	51.21	19.79	157.17
SEm±	22.05	3.45	1.82	14.65
SD	69.72	10.90	5.75	46.33
CV (%)	46.48	21.28	29.05	29.48

Tree biomass refers to the amount of standing dry mass of live or dead matter from tree, whereas, biomass density means presence of biomass in per unit area. The maximum amount of AGBD (141.19 Mg ha^{-1}) in *Pinus roxburghii* in QX and minimum (54.69 Mg ha^{-1}) at QIV. Average AGBD at the site was 93.99 Mg ha^{-1} (Table 2). Similarly, the maximum amount of BGBD (39.53 Mg ha^{-1}) was observed in QX and minimum (15.31 Mg ha^{-1}) at QIV. Average BGBD at the site

Table 2: Biomass and carbon stock of *Pinus roxburghii* in Siwalik hills of Jammu

Quadrate	AGBD	BGBD	TBD	TCD	eCO_2
	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}
I	70.85	19.84	90.68	42.62	156.42
II	88.15	24.68	112.84	53.03	194.63
III	95.22	26.66	121.89	57.29	210.24
IV	54.69	15.31	70.00	32.90	120.74
V	97.44	27.28	124.72	58.62	215.14
VI	139.96	39.19	179.14	84.20	309.00
VII	89.89	25.17	115.06	54.08	198.47
VIII	74.17	20.77	94.93	44.62	163.75
IX	88.31	24.73	113.03	53.12	194.97
X	141.19	39.53	180.72	84.94	311.72
Mean	93.99	26.32	120.30	56.54	207.51
SEm±	8.76	2.45	11.21	5.27	19..35
SD	27.70	7.79	35.47	16.67	61.18
CV (%)	29.48	29.48	29.48	29.48	29.48

was 26.32 Mg ha^{-1} (Table 2). TBD is the summation of AGBD and BGBD, the maximum amount of TBD (180.72 Mg ha^{-1}) was observed in QX and minimum (70.00 Mg ha^{-1}) at QIV. The average TBD at the site was 120.30 Mg ha^{-1} (Table 2). TCD is the C content in the biomass of tree both above and below the ground, it indicates the amount of C entrapped by the tree in its lifetime from the atmosphere. The maximum (84.94 Mg ha^{-1}) TCD was observed at QX and minimum (32.90 Mg ha^{-1}) at QIV. The average amount of TCD at the site was 56.54 Mg ha^{-1} (Table 2). Likewise, CO_2 (eCO_2) sequestered from the atmosphere was observed maximum (311.72 Mg ha^{-1}) at QX and minimum from (120.74 Mg ha^{-1}) QIV. Average eCO_2 at the site was 207.51 Mg ha^{-1} (Table 2). Various factors affect the biomass and carbon stock i.e., photosynthesis rate, solar radiation, forest type, temperature, soil physico-chemical properties, rainfall and duration of growing seasons (Wang et al., 2004). The result for total tree biomass in the present study at the Siwaliks Chir Pine forests of Jammu, is lower than that reported by Banday et al. (2017) from the Siwaliks Chir Pine Forest of Himanchal Pradesh. This variation might be due the impact of different climatic and site factors on the growth of trees and also due the variation in forest age Banday et al. (2017).

Soil physico-chemical properties are of significance as it determines the type of vegetation and the distribution of a species on an area. The data for the soil physico-chemical properties under *Pinus roxburghii* forests in Siwalik hills of Jammu are represented in the Table 3. Soil bulk density was observed maximum (1.73 gm cm^{-3}) from QIII, whereas, minimum (1.23 gm cm^{-3}) from QIX and X. Mean soil bulk density at the site was 1.39 gm cm^{-3} (Table 3). Soil pH was maximum (7.17) at the QI and minimum (5.64) at QIV. Average soil pH on the site was 6.47, means that the soils were slightly acidic (Table 3). Average value of soil electrical conductivity (EC) at the site was 0.13 ds m^{-1} (Table 3). Soil organic carbon (SOC) is of great importance and it act as a sink of C, maximum (7.80 gm kg^{-1}) SOC was recorded at QVI and minimum (4.80 gm kg^{-1}) at QVIII. The average amount of SOC recorded at the site was 6.31 gm kg^{-1} (Table 3). The average amount of NPK (kg ha^{-1})

Table 3: Soil physico-chemical properties under *Pinus roxburghii* forest in Siwalik hills of Jammu

Quadrate	Bulk density	Soil pH	EC	SOC	N	P	K
	gm cm^{-3}		ds m^{-1}	gm kg^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
I	1.27	7.17	0.14	5.90	200.70	29.68	45.68
II	1.49	5.98	0.06	7.10	175.62	22.96	43.65
III	1.73	6.86	0.13	5.10	112.90	25.20	46.58
IV	1.58	5.64	0.08	6.50	283.34	28.22	53.55
V	1.26	6.45	0.16	6.00	244.61	31.70	81.11
VI	1.32	6.70	0.16	7.80	213.25	22.74	46.80
VII	1.40	6.21	0.12	6.00	225.79	28.45	54.90
VIII	1.42	6.46	0.09	4.80	100.35	25.98	51.75
IX	1.23	6.57	0.17	6.80	232.06	26.99	71.66
X	1.23	6.61	0.19	7.10	225.79	23.07	70.88
Mean	1.39	6.47	0.13	6.31	201.44	26.50	56.66
SEm±	0.05	0.14	0.01	0.30	18.12	0.97	4.15
SD	0.17	0.44	0.04	0.93	57.31	3.06	13.13
CV (%)	11.89	6.76	31.91	14.80	28.45	11.56	23.17

at the site was 201.44, 26.50 and 56.66 respectively (Table 3). Soil texture at the site was clay, clay loam and loam (Table 4). Maximum (41.88, 42.07 and 57.05) percent of sand, silt and clay was observed from QVI, QIV and QII. The mean percent of sand, silt and clay at site were 32.44, 30.99 and 36.57 (Table 4). The soils at the site were having hard compaction resulting into higher bulk density with poor drainage (Shapkota and Kafle, 2021), as a result it, may also be one of the reasons for poor growth of vegetation. Soil pH was slightly acidic due to hilly tract, basic soil nutrients are leached or washed out which may be the reason for lower soil pH. The results for the soil pH and soil bulk density are similar to the findings of Sharma et al. (2013) from the foothills of Jammu. SOC was in the medium range Sharma et al. (2013), this may be due to the poor vegetation, high temperature which increases the rate of decomposition and its leaching might be the reason for medium SOC. N and K at site were lower which may be due to poor mineralization and less microbial activities. N content in soil is directly related (93 to 97%) to organic matter (Meysner et al., 2006), low value for available N from the foothills of Jammu have also been reported by Sharma et al. (2009).

Table 4: Percent of soil particles (Sand:Silt:Clay) in soils of *Pinus roxburghii* forest in Siwalik hills of Jammu

Quadrates	0-30 cm (Soil Depth)			
	% Sand	% Silt	% Clay	Soil textural class
I	18.74	30.36	50.90	Clay
II	19.38	23.57	57.05	Clay
III	39.24	27.64	33.12	Clay loam
IV	37.46	42.07	20.47	Loam
V	27.24	41.93	30.83	Clay loam
VI	41.88	28.00	30.12	Clay loam
VII	33.88	38.00	28.12	Clay loam
VIII	35.88	28.00	36.12	Clay loam
IX	41.52	26.00	32.48	Clay loam
X	29.16	24.36	46.48	Clay
Mean	32.44	30.99	36.57	
SEm±	2.69	2.22	3.59	
SD	8.52	7.03	11.34	
CV (%)	26.26	22.69	31.00	

4. Conclusion

Jammu Siwalik hills are characterised by dry hillocks, with rugged and undulating topography and subtropical climate, survival of the *Pinus roxburghii* under such extreme conditions is of importance Therefore, from the present study we can conclude that *Pinus roxburghii* is an important tree species of the Siwalik hills of Jammu and has substantial potential for sequestering the atmospheric carbon contributing to climate change mitigation.

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