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Evaluation of Biomass and Carbon Stocks by Inventory Method in Pure *Pinus roxburghii* Forest in Matta Swat, Khyber Pakhtunkhwa, Pakistan

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Abstract

The present research study was conducted to estimate volume, biomass and carbon stock in pure Pinus roxburghii forest. Forest acts as a source or sinks for atmospheric CO2 to stores from the atmosphere in different carbon pools by trees in a forest. Illegal activities were carried out and were not properly managed. For evaluation of carbon stock study inventory method was conducted and square shape sample plots were selected by stratified random method. A total of 18 plots were taken; the size was 0.1 ha. Elevation and coordinates of each sample plot were measured by GPS. In each sample plot tress height, diameter at (DBH) point and crown cover were measured as a source of primary. Data were analyzed statistically and results were composed in excel and Software Sigma Plot and Past. The results of the present study, the total carbon stocks in all sample plots was 115(Mg^3 0.1H^{-1}) and the mean was 6.407±2.122(Mg 0.1H^{-1}). Total biomass was 230(Mg 0.1 H^{-1}), while the mean was 12.815±4.244($M^3$0.1H^{-1}). The Sum of total carbon stock was 1153.3339(Mg H^{-1}) and the average was 64.074±21.219(Mg H^{-1}). Total biomass was 2306.677(Mg H^{-1}), while the average was 128.149±42.438 (Mg H^{-1}). The study aimed to estimate the volume, stem and total biomass and carbon stock in Pinus roxburghii. The study concluded that it is needed to have Proper scientific management and proper utilization of the forest can be significant measures to enhance the potential of the forest to stored and sink more carbon and control illegal activities.

Keywords: *Carbons stock, stem and total biomass, volume and Basel area*

1. Introduction

Among the greenhouse gases, carbon dioxide (CO2) is the most important gas that is caused by the activities of mankind and increases the cause of climate change and global warming and In June 2014, the concentration of carbon dioxide was 401.30 ppm (Rahman *et al*., 2017). Global climate change is the burning issue among the scientific community because of accelerating carbon dioxide concentration in the atmosphere due to different human activities. According to Intergovernmental Panel on Climate Change (IPCC), the Earth's average temperature increased 0.6o C over the last century and is considered probably to accelerate from 1.4 to 5.8 by the end of the century and Among the greenhouse gases, the major gas is carbon dioxide. (Alessandri, 2019). The greenhouse gases trap the heat in the atmosphere, which keeps the surface of the earth warmer.

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When greenhouse gases increase in quantity, they intensify the greenhouse effect that causes climate change and global warming (Anderson *et al*., 2016). Many human activities like land-use change, fossil fuel burning, and deforestation increase the concentration of carbon dioxide in the atmosphere and cause the problem of climate change and global warming. The concentration of carbon dioxide increases from 280 ppm (pre-industrial time) to 398.79 ppm (Chatterjee *et al*., 2020; Lenka *et al*., 2020).

The IPCC in its fourth assessment report recommended for serious measures to check the problem of global warming to coup the serious ecological, social and economic consequences (Padaria *et al*., 2019; Soltani *et al*., 2020). Terrestrial ecosystem, oceans, atmosphere and geological reservoirs are the main components of the global carbon cycle. Among terrestrial ecosystem, forest ecosystem has the significant potential to store and sink carbon and therefore globally forest is considered a potential tools to mitigate global climate change (Kalliokoski *et al*., n.d.; Schimel *et al*., 2015). Forest is one of the most vital carbon sinks. According to the Kyoto protocol, the forest is defined as the ecosystem which achieves 30% of canopy cover with 5 m height and should cover the 1-hectare area with a width of more than 30 m. Five carbon are present which in deadwood carbon, carbon present below ground, carbon present above ground, soil organic carbon and carbon present in the fine litter (Schoene *et al*., 2007). Forest ecosystem stores 20 to 50 more carbon as compared to other ecosystems due to its woody character and long life span (Köhl *et al*., 2015). Forest covers 31% of the total land area, about 4 billion ha of the land is covered by the forest. The total estimated growing stock of the world forest is 527 billion m3, while the total stored carbon in world forest is 650 billion tons (Global Forest Resources Assessment 2010, n.d.; Karsenty *et al*., n.d.). In a forest ecosystem carbon should be measured in different carbon pools that include carbon store in above-ground biomass, below-ground biomass, deadwood, litter, and soil. To measure the carbon in a forest the biomass data of the forest is required (Petrokofsky *et al*., 2012). For the estimation of above-ground biomass in a forest the growing stock volume is the required parameter (Wassihun *et al*., 2019). Being a participant of the Kyoto Protocol, they store carbon in the different forest types of Pakistan will be evaluated. In Pakistan, the forest department conducts inventory on regular basis for the measurement of the growing stock in the shape of working plan and can be used to assessed carbon stock, but these estimates can be error-prone (Khan *et al*., 201Khan *et al*., 2015; Raqeeb *et al*., 2014). The present study was conducted in the pure Pinus roxburghii forest of Swat KPK, Pakistan. In Pakistan Chir pine (Pinus roxburghii) forest is distributed in Dir, Chitral, Gilgit, and Swat. No proper scientific study has been conducted in Pakistan concerning the growing stock, biomass and carbon stocks measurement of the Pinus roxburghii forest stand. The present study provides detailed information and field protocol regarding biomass and carbon stock in the chir (Pinus roxburghii) forest. A recent research study was conducted in the pure Pinus roxberghii forest of Matta Swat KPK Pakistan. The study provides detailed information and field protocol regarding, Basel area, volume, biomass and carbon stock. The Objectives of the study were to evaluate the Basle area, volume, stem, and total biomass and carbon stock in the pure Pinus roxburghii forest of Swat Khyber Pakhtunkhwa, Pakistan.

2. Materials and method

2.1 Study site

Our research study was conducted in the pure *Pinus roxberghii* forest of Matta Swat KPK Pakistan. The total area of study area chir forest was 280 hectares. Area of the soil is generally fertile and favorable for forestry This area has been given to Wild Life Department, KPK and is declared as a game reserve. The elevation of the Matta Swat area ranges from 3010 to 3680 ft. The mean minimum and maximum temperatures of 6 °C and 36 °C respectively, are recorded in December and June recorded at the meteorological station of Saidu Sharif. The study site is located about 28 km from the central city of Mingora. The area receives 1100-1250 mm annually average precipitation as recorded by Saidu Sharif metrological station. Matta is a big city of Swat KPK.

2.2 Research design

The researcher visited Matta for the collection of our research data in matta Swat KPK, Pakistan. In the selected study site, pure vegetation of *Pinus roxburghii* was found. Sample plots were selected stratified randomly within the Chir forest. A total of 18 plots were taken from the forest area. The size of each plot was fixed to be 0.1 ha and square-shaped plots were taken (Dimension 33×33 m2). Elevation and coordinates (m) of every sample plot were measured by GPS. GPS was used for taking the location and to find out the elevation of every sample plot. By climbing, Staff rod and Spiegel Relaskope was used for tree height measurement, the caliper was used for taking the diameter of the tree, the tape was used to measure dimensions of the sample plot. The diameter of each tree in every plot was measured by diameter tap at two point's i.e. At the basal point and at the point where the first branch starts and the crown cover was measured by measuring tape. For the measurement of diameter at the midpoint, we climbed the tree and recorded the diameter by using diameter tape and calipers.

2.3 Measurement Tree volume

Diameter at breast height was measured for tree cylindrical volume calculation and diameter at midpoint was measured for actual volume calculation. To calculate stem volume (m3 ha-1), tree height (m) and diameter of the tree (cm) at DBH were measured. The height of the tree was measured by Abney's level. The tree diameter was measured by Caliper. Basel area was calculated from DBH point and the following formula was used to find out stem and tree volume.

$$B.A = 1/4\pi\ D^2$$

Tree volume was estimated by the following formula;

$$V\ (m^3\ ha\text{-}1) = 1/4\pi\ D^2 \times H \times FF$$

Whereas V = Volume of stem (m3 ha-1), H = Height of tree in meter, B.A = Cross-sectional Basel area at DBH point and FF = form factor. For the present study, the form factor for each tree in the respective diameter class was calculated.

2.4 Calculation of stem and total biomass

Biomass of stem (t ha-1) was estimated from (BWD) basic wood density (kg m^{-3}) and volume (m^3 ha-1). The value of (BWD) was taken from the literature. To find out stem biomass, the formula used was:

Biomass of stem (Kg) = Volume of the stem (m^3) × Basic wood density (kg m^{-3})

Measurement of total biomass was done by using the biomass expansion factor. The biomass expansion factor is the ratio between stem biomass and total biomass. It means the contribution in making the total biomass of a tree by different parts of the tree i.e., leaves, root, stem, and twigs, etc. To calculate the total biomass, the stem biomass is multiplied with the BEF. The formula used for that is given as under:

The Biomass expansion factor (BEF) was taken as 1.51. The biomass (t/ha) of other tree components (leaves, branches, and roots) were estimated from stem biomass using published Biomass Expansion Factors (BEF) for this tree species (Nizami, 2012).

Total biomass (T ha-^{l}) = BEF x stem biomass (T ha-^{l})

2.5 Estimation of carbon stock

For the estimation of total carbon stock, we used conversion factor 0.5. For the calculation of total carbon stock, we multiplied the conversion factor with total biomass. This conversion factor is used internationally. To estimate the total carbon stock, the following formula was used. The conversion factor is constant (0.5) in the formula. This conversion factor has been globally used by (Khan *et al*., 2015).

Total carbon stock = Conversion factor × Total biomass

2.6 Statistical analysis

To study the data statistically, the primary data that was taken in sample plots during field inventory and were analyzed Microsoft, Excel. The formulas were used to find out the results by using simple Excel. The statistics univariates were used to find out the Mean, SD, CV (%) and Standard Error of sum of all sample plots with the plot level for different parameters i.e. volume and basal area, stem biomass, total biomass, carbon stocks were also calculated through Excel. Tables and graphs were formed in Excel, statistics univariates were applied in past version 10.

3. Results and Discussion

The results of the present study were calculated the area of the minimum base was 0.949m^2 (M^2 0.1H^{-1}) in plot no.1. at elevation 1148m, while the maximum Basel area was 3.088m^2 (M^2 0.1H^{-1}) with the elevation 1391m. The average Basel area was 1.928±0.615 (M^2 0.1H^{-}), while the sum of the Basel area in all sample plots was 34.695 (M^2 0.1H^{-1}) which is given in **Table 1**. The results show that at low elevation there was a calculated low Basel area while at higher elevation it was calculated more Basel area which is given in **Table 1**.Total minimum trees volume was 8.427(M^3 0.1H^{-1}) in plot no 2 at elevation 1170m, while the maximum tree volume was 30.369m^3/0.1 hectare at, higher elevation with 1395m at plot No: 18. The average trees volume was 18.449±6.110 (M^3 0.1H^{-1}) while the sum of the tress volume in all sample plots was 332.087(M3 0.1H^{-1}) which is shown in **Table 1**. At low elevation has calculated a low amount of tress volume which gradually increases with elevation there were calculated more tree volume in 0.1hac which are given in **Table 1**. The total sum of stem biomass in all sample plots was 152.760 (Mg 0.1H^{-1}) while the average stem biomass was 8.487±2.810 (Mg 0.1H^{-1}) which is shown in **Table 1**. The minimum stem biomass was 3.876 (Mg 0.1H^{-1}) at elevation 1170m in plot No; 02 while the maximum was 13.970 (Mg 0.1H^{-1}) which is given in Error! Reference source not found.. It concluded that at low elevation in plot no 2 having low stem biomass while at higher elevation 1390m having more stem biomass in plot no 18 at higher elevation 1191m.

The Sum of total biomass in all samples plot was 230.668 (Mg 0.1H^{-1}, while the mean was 12.815±4.244 (Mg 0.1H^{-1}) which is shown in **Table 1**. The minimum total biomass was 5.853 (Mg 0.1H^{-1}) at low elevation 1170m in plot no 2, although the maximum total biomass was 21.094 (Mg 0.1H^{-1}) in plot no 18; with the elevation 1395m which are given **Table 1**. The average total carbon stock was 6.407±2.122 (Mg 0.1H^{-1}), while the sum of the total carbon stock in all sample plots was 115.334 (Mg 0.1H^{-1}) which are shown in **Table 2.** The minimum total carbon stock was 2.927 (Mg 0.1H^{-1}) with the elevation 1170 m while the maximum carbon stock was 10.547 (Mg 0.1H^{-1}) with higher elevation 1395m which is given in **Table 1**. The results concluded that pure *Pinus roxburghii* forest with low elevation have calculated the low amount of Basel area, volume, stem, and total biomass and carbon stock while gradually at higher elevation have evaluated the higher amount of volume biomass and carbon stock which are given in **Table 1**.. The statistical value of coefficient variance, median, standard deviation, standard error, and variance are given in **Table 2**. for Basel area, tree volume, stem, and total biomass and carbon stocks in (0.1 hectares).

Figure 1 shows the data explanation of **Table 1**. It shows the Basel area, volume, stem, and total biomass and carbon stock in sample plots. The figure shows that in plot no 1 at low elevation 1170m evaluated the low amount of Basel area, volume, biomass, and carbon stocks while as compared to plot no 18 at higher elevation 1395m have calculated more amount of biomass and carbon stock.

Figure 1 concluded on the base of recent research study at low elevation in *Pinus roxburghii* forest has an estimated low amount of biomass and carbon stock while at higher elevation has calculated more amount of biomass and carbon stocks which are shown in **Figure 1**.

Table 1. Show elevation of plots with Basel area, stand volume, total and stem biomass, and carbon stock in (0.1 h^{-1})

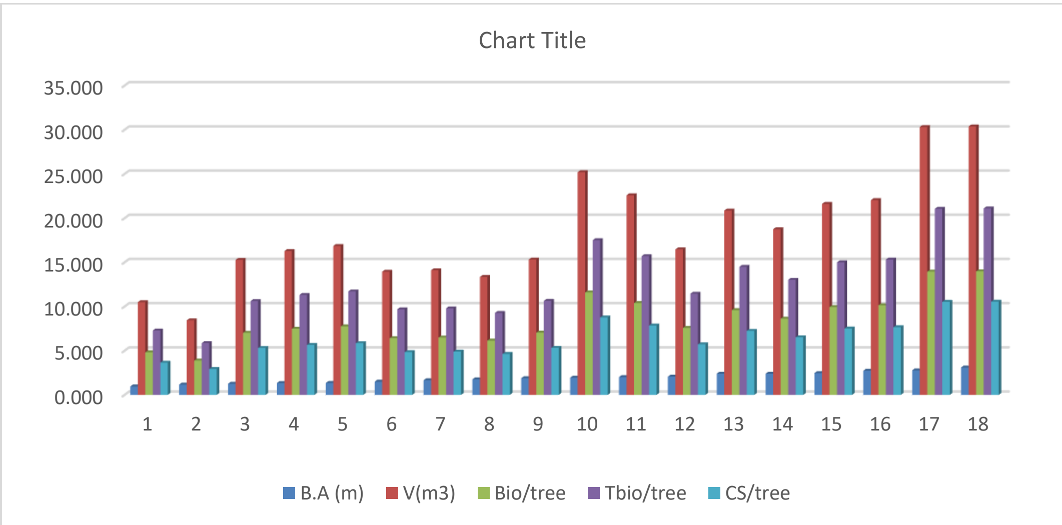
ID Plot	Elevation (m dpl)	Basel Area $M^2 h^{-1}$	Stand Volume $M^3 h^{-1}$	Stem Biomass $Mg h^{-1}$	Total Biomass $Mg h^{-1}$	Carbon Sock $Mg h^{-1}$
1	1150	0.949	10.482	4.822	7.280	3.640
2	1170	1.159	8.427	3.876	5.853	2.927
3	1185	1.251	15.272	7.025	10.608	5.304
4	1197	1.336	16.265	7.482	11.298	5.649
5	1212	1.352	16.841	7.747	11.697	5.849
6	1230	1.490	13.933	6.409	9.678	4.839
7	1240	1.663	14.089	6.481	9.787	4.893
8	1253	1.752	13.341	6.137	9.267	4.633
9	1263	1.886	15.308	7.042	10.633	5.316
10	1271	1.941	25.197	11.591	17.502	8.751
11	1282	2.015	22.584	10.389	15.687	7.844
12	1290	2.063	16.460	7.572	11.433	5.717
13	1299	2.390	20.848	9.590	14.481	7.240
14	1310	2.392	18.730	8.616	13.010	6.505
15	1323	2.463	21.602	9.937	15.004	7.502
16	1346	2.731	22.035	10.136	15.306	7.653
17	1370	2.774	30.304	13.940	21.049	10.525
18	1395	3.088	30.369	13.970	21.094	10.547

Source: Author

Table 2. Determine statistical values standard deviation, standard error, coefficient variance, and variance for Basel area (m2), volume (m3), stem and total biomass (tons) and carbon stocks in (tons)/ 0.1 hectares

Variable	*Unit*	*N*	*Min*	*Max*	*Mean*	*Sum*	*SD*	*CV (%)*
Basle area	M^2 $0.1H^{-1}$	18	0.949	3.088	1.928	34.695	0.615	31.909
Tree volume	M^3 $0.1H^{-1}$	18	8.427	30.369	18.449	332.087	6.11	33.116
Stem biomass	M $0.1H^{-1}$	18	3.876	13.97	8.487	152.76	2.81	33.116
Total Biomass	M $0.1H^{-1}$	18	5.853	21.094	12.815	230.668	4.244	33.116
Carbon stock	M $0.1H^{-1}$	18	2.927	10.547	6.407	115.334	2.122	33.116

Source: Author



Source: Author

Figure 1. Describe some of the Basel area (m2), volume (m3), Stem biomass (tons), total biomass (tons) and carbon stocks (tons)/Plot (0.1 Hectare)

The recent research study calculated the sum of total biomass in all samples plot was 2306.677 (Mg H^{-1}), while the mean was 128.149± 42.438 (Mg H^{-1}) which is shown in **Table 4.** The minimum total biomass was 58.534 (Mg H^{-1}) at low elevation 1170m in plot no 3, although the maximum total biomass was 21.094 (Mg H^{-1}) in plot no 18; with the elevation 1395m which are given the **Table 3**. The average total carbon stock was 64.07±21.219 (Mg H^{-1}), while the sum of the total carbon stock in all sample plots was 1153.339 (Mg H^{-1}) which are shown in **Table 4**. The minimum total carbon stock was 29.267 (Mg H^{-1}) with the elevation 1170m while the maximum carbon stock was 105.472 (Mg H^{-1}) with higher elevation 1391m which is given in **Table 3.**The results concluded that pure *Pinus roxburghii* forest with low elevation have calculated the low amount of Basel area, volume, stem, and total biomass and carbon stock while gradually at higher elevation have evaluated the higher amount of volume biomass and carbon stock which are given in **Table 3.** The total sum of stem biomass in all sample plots was 1522.601 (Mg H^{-1}) while the average stem biomass was 84.867±28.105 (Mg H^{-1}) which is shown in **Table 4.** The minimum stem biomass was 38.764 (Mg H^{-1}) at elevation 1170m in plot no 2 while the maximum was 139.698 tons/hectare which is given in **Table 3.** It concluded that at low elevation in plot no 2 having low stem biomass while at higher elevation 1390m having more stem biomass in plot No: 18 at higher elevation 1395m.

The results of the present study were calculated the minimum Basel area was 9.491 (M^2 H^{-1}) in plot no 1 at elevation 1150m, while the maximum Basel area was 30.877 (M^2 H^{-1}) with the elevation 1390m. The average Basel area was 19.279±6.151 (M^2 H^{-1}), while the sum of the Basel area in all sample plots was 346.953 (M^2 H^{-1}) which are given in **Table 4.**The results show that at low elevation there was a calculated low Basel area while at higher elevation it was calculated more Basel area which is given in **Table 3.**Total minimum trees volume was 84.27(M^3 H^{-1}) in plot no 2 at elevation 1180m, while the maximum tree volume was 303.691 (M^3 H^{-1}) at, higher elevation with 1395m at plot no 18. The average tree volume was 184.493±61.097 (M^3 H^{-1}) while the sum of the tress volume in all sample plots was 3320.871 (M^3 H^{-1}) which is shown in **Table 4.**

At low elevation has calculated a low amount of tress volume which gradually increase elevation there were calculated more tree volume/hectare which are given in **Table 3.** The coefficient variance, median, standard deviation, standard error, and variance are given in **Table 4.** for the Basel area, tree volume, stem, and total biomass and carbon stocks/hectares.

Table 3. Shows sum of Basel area (m2), volume (m3), Stem biomass (tons), total biomass (tons) and carbon stocks (tons)/Hectares

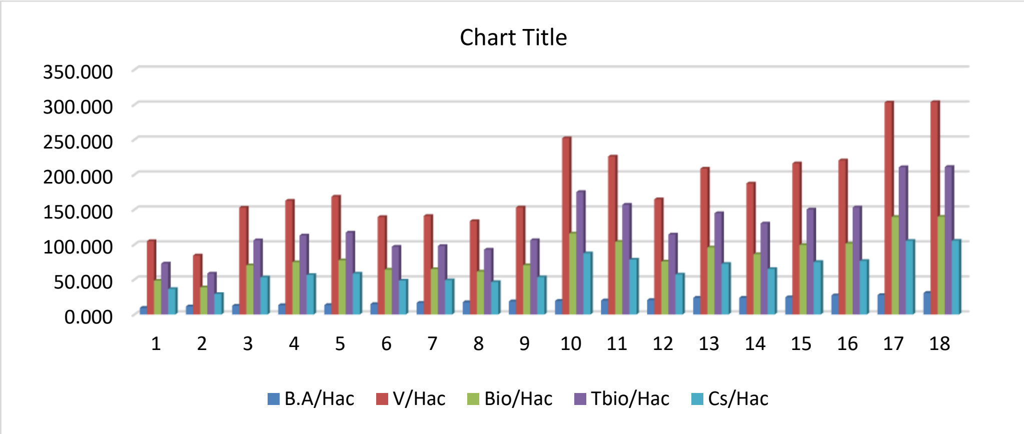
Basel Area (m^2)	*Stand Volume M^3 h^{-1}*	*Stem Biomass Mg h^{-1}*	*Total Biomass Mg h^{-1}*	*Carbon Stock Mg h^{-1}*
9.491	104.816	48.215	72.805	36.402
11.588	84.270	38.764	58.534	29.267
12.515	152.715	70.249	106.076	53.038
13.362	162.654	74.821	112.979	56.490
13.520	168.406	77.467	116.975	58.487
14.899	139.334	64.094	96.781	48.391
16.628	140.895	64.812	97.866	48.933
17.520	133.410	61.369	92.667	46.333
18.864	153.080	70.417	106.330	53.165
19.411	251.973	115.908	175.021	87.510
20.148	225.844	103.888	156.871	78.435
20.627	164.600	75.716	114.331	57.166
23.901	208.476	95.899	144.807	72.404
23.920	187.301	86.158	130.099	65.050
24.633	216.016	99.367	150.045	75.022
27.314	220.350	101.361	153.055	76.527
27.736	303.042	139.399	210.493	105.247
30.877	303.691	139.698	210.943	105.472

Source: Author

Table 4. Shows statistical values standard deviation, standard error, coefficient variance, and variance for Basel area (m2), volume (m3), stem and total biomass (tons) and carbon stocks in (tons)/ hectares

Variable	*Unit*	*N*	*Min*	*Max*	*Mean*	*Sum*	*SD*	*CV (%)*
Basle area	M^2 h-1	18	9.491	30.877	19.275	346.953	6.151	31.909
Tree volume	M^3 h-1	18	84.27	303.691	184.493	3320.871	61.097	33.116
Stem biomass	M h-1	18	38.764	139.698	84.867	1527.601	28.105	33.116
Total Biomass	M h-1	18	58.534	210.943	128.149	2306.677	42.438	33.116
Carbon stock	M h-1	18	29.267	105.472	64.074	1153.339	21.219	33.116

Source: Author



Source: Author

Figure 2. Explain some of the Basel area (m2), volume (m3), Stem biomass (tons), total biomass (tons) and carbon stocks (tons)/Hectare

Figure 1 Describes the data in **Table 3**. It shows the Basel area, volume, stem, and total biomass and carbon stock in sample plots. The figure shows in plot no 1 at low elevation 1170 m estimated the low amount of Basel area, volume, biomass and carbon stocks while as compared to plot no 18 at higher elevation 1395m have calculated more amount of biomass and carbon stock which are given in **Table 3**.

Figure 1 concluded on the base of the current research study at low elevation in the *Pinus roxburghii* forest has an estimated low amount of biomass and carbon stock while at higher elevation has calculated more amount of biomass and carbon stocks which are shown in **Figure 2.**

Conclusion and recommendation

The present research study was conducted in the *Pinus roxburghii* forest of Swat KPK, Pakistan. The objectives of the study were to estimate the biomass ad carbon stocks in the chir forest. In the results, the sum of the total biomass was 2306.677 (Mg H^{-1}), while the carbon stock was 1153.339 (Mg H^{-1}) and the total volume was 3320.871 (M^3 H^{-1}) tons/ hectares which are given in **Table 2.** *Pinus roxburghii* forest is a valuable sink for carbon sequestration. Illegal logging uses of fuelwood, grazing was carried out in it and d no proper utilization and unscientific management plan. *Pinus roxburghii* forest needs the proper scientific management plan and proper utilization. By rehabilitation of degraded forest stand, afforestation, and reforestation can increase the potential of the *Pinus roxburghii* forest to sorted more carbon from the atmosphere and acts as a sink for carbon.

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