

Research Article

Patterns of Biomass and Carbon Allocation across Chronosequence of Chir Pine (*Pinus roxburghii*) Forest in Pakistan: Inventory-Based Estimate

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The quantitative relationship between carbon sequestration potential and stand ages of Pine (*Pinus roxburghii*) forest is not documented in Pakistan. Using field inventory data, this study underlines the patterns of biomass and carbon allocation across a chronosequence of Chir Pine forest. Based on the uniform shelterwood silvicultural management system, the forest was classified into three stand age classes representing the young stand (<50 years), mature stand (50–75 years), and overmature stand (> 75 years). The results showed an increasing trend in living tree biomass carbon with stand age. However, soil carbon showed gradually decreasing trend from young to overmature stand. Similarly, deadwood, litter, and understory biomass carbon showed an increase pattern of changes. Altogether, the results highlighted that the mean carbon values of all components varied between 90.3 t·C·ha⁻¹ in the young stand and 309.5 t·C·ha⁻¹ in the overmature stand. Furthermore, our results confirm that the current management operations affect the forest floor and soil carbon. Therefore, we suggest that different protection measures should be considered during management operations to enhance soil and forest floor carbon.

1. Introduction

Biomass and carbon storage in any forest ecosystem play a multiple and significant role in the global carbon cycle [1]. Forest ecosystems have more potential of storing carbon than another terrestrial ecosystem [2]. In a forest, carbon is stored in different pools, but tree and soil are the main components that store more carbon than other components [2–5]. In order to enhance the global carbon sequestration and to increase carbon-absorbing capacity, reforestation, afforestation, and the preservation of existing forest have been suggested as an effective way for mitigation of elevated CO₂ concentrations [6–8]. The contribution of forest carbon storage in total carbon of terrestrial ecosystem is significantly

important. Generally, forest stand development has a strong relationship with carbon pools of forest ecosystem because tree growth rate of forest ecosystem mostly varies with stand age [8, 9]. Trees increase their biomass as well as enhance growth by absorbing CO₂ from the atmosphere and sequester it in different tree components [10]. As biomass increases, the growth of tree species also increases [11]. Carbon sequestration of a forest depends on forest type, forest stand age, and dominant tree species [11]. Previous studies showed that forest stand age may have a significant effect on the carbon stock among different ecosystem components [12].

Stand age is an important factor affecting storage of carbon in a forest in various components such as in a tree,

understory, deadwood, and soil [6, 13, 14] and a strong predictor of the structure and function of a forest ecosystem which may affect the carbon density among carbon pools [15]. Furthermore, various carbon pools of a forest respond differently to stand age [16]. Therefore, it is important to understand the relationship of stand age with different carbon components and sequestration rate [17]. A number of studies underline the effect of stand age on carbon allocation among different carbon banks [6, 7, 18]. The biomass carbon of living trees increases with an increase in stand age [19, 20]. However, this increasing trend followed a sigmoidal trend, as young trees carbon grow rapidly up to a certain age and then gradually decline [21].

In Pakistan, the researchers mainly focused on the measurement of forest carbon in the subtropical forest [22], temperate forest [23–25], and in the planted forest [26]. However, no up-to-date studies have been carried out on the carbon allocation with respect to stand age. In addition, biomass carbon measurement is based on already available inventory data in which the minimum diameter is selected from 10 cm to 16 cm in various forests types of Pakistan, which may underestimate the available carbon storage and sequestration rate [22]. In order to assess the carbon allocation among different carbon pools in relation to stand age, the present study was conducted in subtropical Chir forest. *Pinus roxburghii* is the dominant species of subtropical Chir zone in Pakistan. It is widely distributed in the Murree Hill including Dir, Swat, and Azad Kashmir. Large plantations have been raised in Mansehra and Abbottabad areas of KPK. It is mostly found in the form of monospecific community. This species is easily cultivated and naturally regenerated in the northern area of Punjab and KPK province and considered as fast-growing and valuable species for forestation and reforestation of denuded areas of Pakistan [27].

Subtropical Chir Pine forest is managed under shelterwood management system. Under this system, the area of the forest is divided into different blocks on the base of age carrying with different management operations. Cutting and felling operations are concentrated to overmature blocks, thinning operation are carried out in mature block, and cleaning operations are in the young block. These management operations in various blocks may affect the carbon allocation in different carbon pools particularly in the litter, deadwood, and soil. Thus, complete accurate information is needed regarding biomass and carbon storage in different age stand of the Chir with respect to the current management operations. Therefore, we designed this study with overall objectives of assessing biomass and carbon stock of *P. roxburghii* forest ecosystem on basis of stand age and outlining the effect of management practices on carbon stock in respective stand age classes.

2. Materials and Methods

2.1. Study Area. The study was carried out in Murree Hill of Pakistan. The latitude and longitude of the study area range from 33° 47' 15" to 33° 54' 47" N and from 73° 16' 54" to 73° 29' 18" E. The elevations from sea level range from 939 to 1873 m. The average precipitation varies from 500 to

1200 mm while temperature ranges from -5°C in winter to 40°C in summer in the study area. The rocks are sedimentary in origin and comprise of shales, sandstones, limestone, and marls. The soil is loamy in nature with a variable proportion of sand, silt, and clay [27]. The study site is the natural zone of Chir forest that is managed under shelterwood system. The dominant tree species of the area is Chir Pine (PR). The major associated tree species are *Pinus wallichiana* (kail), *Quercus incana* (rhin), and *Pyrus pashia* (batangi). The associated understory flora includes *Myrsine africana* (khukhal), *Berberis lycium* spp. (sumblu), *Carrisa spinarum* (granda), *Dodonaea viscosa* (sanatha), *Adhatoda vasica* (Bahekar), *Capparis decidua* (karir), and *cannabis sativa* (Bang) (Figure 1).

2.2. Description of Shelterwood System and Research Design. Based on the uniform shelterwood silvicultural system, the forest area is divided into four periodic blocks (PBI, PBII, PBIII, and PBIV) on the base of rotation age (100 years) and regeneration period (25 years), thus forming four age stands that are (1–25, 26–50, 51–75, and 76–100 years). Under this system, the first in the mature crop (PBIV), a regeneration felling, is carried out in which all the trees are not felled, but prescribed numbers of trees (seed bearers) are retained over the area for seed production. Mostly, $10\text{--}20$ trees $\cdot\text{ha}^{-1}$ are retained for the seed production. When the regeneration is established, then the final felling is carried out to remove the seed bearers for the development of the new crop. The regeneration and final felling are completed in 25 years. In PBIII, the thinning operations are carried out with the object to enhance the growth and to prepare the crop for felling. Thinning is mostly concentrated in the lower diameter classes. In PBII, and PBI thinning and cleaning operations are carried out. A theoretical sketch of the system is given in Table 1.

Because of the same management operations in PBI and PBII, we placed these two periodic blocks into young age class (1–50 years). Similarly, PBIII represents the mature stand (50–75 years) and PBIV represents overmature stand (>75 years). In each block, sample plots were selected randomly for data collection. The size of each sample plot size was $20\text{ m} \times 30\text{ m}$. In each plot, tree diameter (cm) and height (m) along with stem density (ha^{-1}) were measured. In each sample plot of the respective block, subplots of 1 m^2 were laid out for soil samples collection. Similarly, samples were also collected from these subplots for the litter, deadwood, and understory carbon analysis.

2.2. Biomass Inventory. Tree volume was determined from tree basal area, tree height, and form factor (Equation (1)) [28]. The value of form factor was sourced from the literature [29]. From tree volume ($\text{m}^3\cdot\text{ha}^{-1}$) and basic wood density (kg m^3), stem biomass was calculated (Equation (2)). The basic wood density (BWD) value was obtained from the available literature [30]. The total (above and below ground) biomass ($\text{t}\cdot\text{ha}^{-1}$) was obtained from stem biomass ($\text{m}^3\cdot\text{ha}^{-1}$), biomass expansion factor (BEF), and root to shoot ration (R) following IPCC (2006) guidelines (Equation (3)).

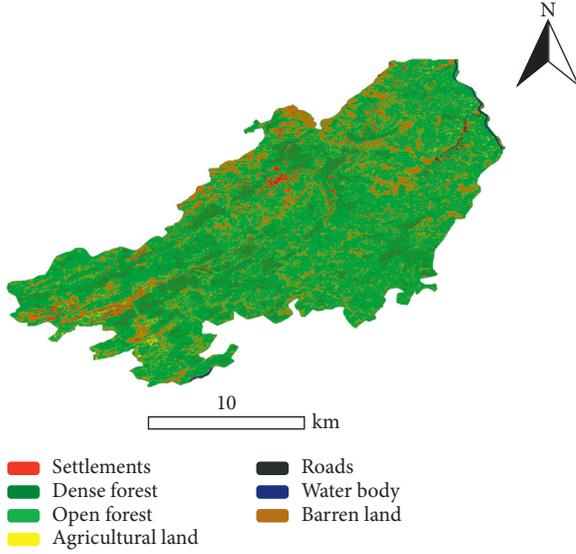


FIGURE 1: Study area: Muree Hill, Punjab, Pakistan.

TABLE 1: Theoretical sketch of the system.

Periodic blocks	Age at the time of formation	Age at the end of regeneration period
PBI	1–25	77–100
PBII	26–50	51–70
PBIII	51–71	26–50
PBIV	76–100	1–25

The BEF and R values were obtained from the literature [22, 26, 30–32]. The whole relations are as follows:

$$\text{tree volume (m}^3 \cdot \text{ha}^{-1}) = \frac{\pi}{4} \times D^2 \times H \times F, \quad (1)$$

where BA = basal area ($\text{m}^2 \cdot \text{ha}^{-1}$), H = total tree height (m), and F = form factor. The value of FF was sourced from the previous literature [26, 29]:

$$\text{stem biomass (t} \cdot \text{ha}^{-1}) = \text{basic wood density (kg/m}^3) \times \text{volume (m}^3), \quad (2)$$

$$\text{total biomass (t} \cdot \text{ha}^{-1}) = \text{stem biomass (t} \cdot \text{ha}^{-1}) \times \text{BEF} \times R. \quad (3)$$

For the biomass estimation of herbs, the vegetation was destructively harvested. Similarly, the deadwood and litter were also collected within 1 m^2 subplots following [22–26, 33]. The fresh weight of all samples was recorded, and then one Kg subsample was transferred to the laboratory and dried at 72°C for 48 hours for biomass measurement and then extrapolated to the contemporary weight of the whole plot [34–36]:

$$\text{Biomass (t} \cdot \text{ha}^{-1}) = \frac{\text{WS}}{\text{A}} \times \frac{\text{WDS}}{\text{WFS}} \times \frac{1}{10,000}, \quad (4)$$

where WS = weight of wet field sample in gram (g), WDS = weight of dry subsample in gram (g), WFS = weight

of fresh dry subsample in Gram (g), and A = area in hectare (ha).

2.3. Carbon Stocks Assessment. The carbon stocks values in trees, herbs, and deadwood were calculated from biomass using a conversion factor having value 0.5 (Equation (5)) [22, 23, 34–37]:

$$\text{carbon stock (t} \cdot \text{ha}^{-1}) = \text{biomass (t} \cdot \text{ha}^{-1}) \times 0.5. \quad (5)$$

The carbon stocks values in litter were calculated from biomass using a conversion factor having value 0.47 (Equation (6)) following IPCC (2006) guidelines:

$$\text{carbon stock (t} \cdot \text{ha}^{-1}) = \text{biomass (t} \cdot \text{ha}^{-1}) \times 0.47. \quad (6)$$

2.4. Soil Organic Carbon. For the estimation of soil carbon stock, soil samples were taken with soil auger at the depth of 0–15 cm and 16–30 cm in each plot. The weight of each sample was measured in the field, and the samples were put in labeled bags and were brought to the laboratory for further analysis. The soil bulk density ($\text{g} \cdot \text{cm}^{-3}$) of each sample was measured from the weight of soil sample and volume of the core. Soil carbon content was measured following the procedure of Walkley and Black method [38], and soil carbon in $\text{t} \cdot \text{ha}^{-1}$ was calculated from the following equation [22, 23, 39]:

$$\text{soil carbon (t} \cdot \text{ha}^{-1}) = \text{SBD (g/cm}^3) \times \text{SOC (\%)} \times \text{SHT (cm)} \times 100, \quad (7)$$

where SBK = soil bulk density (g/cm^3), SOC = soil organic content (%), and SHT = soil horizon thickness (cm).

2.5. Statistical Analysis. Statistical software (sigma plot 12.5) was used for the manipulation of statistical data. Regression models were developed for the relationship between diameter (cm) and tree height (m), basal area ($\text{m}^2 \cdot \text{ha}^{-1}$), and volume ($\text{m}^3 \cdot \text{ha}^{-1}$), biomass ($\text{t} \cdot \text{ha}^{-1}$) and carbon stocks ($\text{t} \cdot \text{ha}^{-1}$). One-way ANOVA (all pairwise comparison) was applied to test the significance of the means values.

3. Results

3.1. Growing Stock and Biomass. The results revealed that the average stem density ranged from 636 ± 93.7 ($\text{trees} \cdot \text{ha}^{-1}$) in the young stand to 147 ± 56.7 ($\text{trees} \cdot \text{ha}^{-1}$) in the overmature stand. A statistical higher stem density was found in the young stand while lower stem density was found in the overmature stand. The basal area in young, mature, and overmature stands was 15.51 ± 1.6 ($\text{m}^2 \cdot \text{ha}^{-1}$), 35.57 ± 18.0 ($\text{m}^2 \cdot \text{ha}^{-1}$), and 45.91 ± 15.1 ($\text{m}^2 \cdot \text{ha}^{-1}$), respectively. Statistically, no significant variation was found in the mature and overmature stand in the basal area; however, young stand showed significantly lowest basal area. The highest total volume was found in the overmature stand, while lowest volume was recorded in the young stand (Table 2). Further regression analysis between basal area and volume showed a significant relationship among all stands (Table 3). The characteristics of growing stock are figured in Table 2.

TABLE 2: Growing stock characteristics of Chir Pine forest.

Age group	Mean DBH (cm)	Mean height (m)	Mean basal area ($\text{m}^2 \cdot \text{ha}^{-1}$)	Mean stand density (trees ha^{-1})	Mean stand volume ($\text{m}^3 \cdot \text{ha}^{-1}$)
Young	17.4 ± 1.5	9.6 ± 1.8	15.5 ± 1.6 ^B	636.6 ± 93.7 ^{A>}	83.0 ± 12.9 ^C
Mature	41 ± 5.9	18.9 ± 4.2	35.5 ± 18.0 ^A	267 ± 115.7 ^B	356.0 ± 105.9 ^B
Overmature	63.8 ± 11.5	19.7 ± 5.7	45.9 ± 15.1 ^A	147.6 ± 56.7 ^C	549.4 ± 107.1 ^A
Mean	40.7	16.0	32.3	350.4	329.4

Superscripts in each column show significant differences at $\alpha=0.1$ and $p \leq 0.0001$.

TABLE 3: Relationship type, equation, and R^2 value of the *Pinus roxburghii* stands.

Age class	Parameters	Relationship type	Equation	R^2 value
Young stand	BA & V	Polynomial, quadratic	$f = -0.07 + 3.53 * x + 0.86 * x^2$	0.94
	BA & STBM	Polynomial, quadratic	$f = -0.04 + 2.15 * x + 0.52 * x^2$	0.94
	BA & TBM	Polynomial, quadratic	$f = -0.07 + 3.25 * x + 0.80 * x^2$	0.94
	BA & TCS	Polynomial, quadratic	$f = -0.03 + 1.62 * x + 0.40 * x^2$	0.94
	D & H	Polynomial, quadratic	$f = -4.22 + 0.90 * x + -0.00 * x^2$	0.99
Mature stand	BA & V	Polynomial, quadratic	$f = -0.99 + 10.01 * x + 0.09 * x^2$	0.99
	BA & STBM	Polynomial, quadratic	$f = -0.60 + 6.11 * x + 0.05 * x^2$	0.99
	BA & TBM	Polynomial, quadratic	$f = -0.92 + 9.22 * x + 0.08 * x^2$	0.99
	BA & TCS	Polynomial, quadratic	$f = -0.46 + 4.61 * x + 0.04 * x^2$	0.99
	D & H	Polynomial, quadratic	$f = -0.08 + 0.77 * x - 0.00 * x^2$	0.99
Overmature stand	BA & V	Polynomial, quadratic	$f = -0.87 + 12.93 * x - 0.08 * x^2$	0.99
	BA & STBM	Polynomial, quadratic	$f = -0.53 + 7.88 * x - 0.05 * x^2$	0.99
	BA & TBM	Polynomial, quadratic	$f = -0.80 + 11.91 * x - 0.08 * x^2$	0.99
	BA & TCS	Polynomial, quadratic	$f = -0.40 + 5.95 * x - 0.04 * x^2$	0.99
	D & H	Polynomial, quadratic	$f = 8.65 + 0.45 * x - 0.00 * x^2$	0.99

BA = basal area ($\text{m}^2 \cdot \text{ha}^{-1}$), V = volume ($\text{m}^3 \cdot \text{ha}^{-1}$), STBM = stem biomass ($\text{t} \cdot \text{ha}^{-1}$), TBM = total biomass ($\text{t} \cdot \text{ha}^{-1}$), D = diameter (cm), and H = height (m).

The total tree biomass distribution of Chir Pine forest of the young, mature, and overmature stand was recorded at 80.0 ± 12.4 ($\text{t} \cdot \text{ha}^{-1}$), 343.1 ± 167.6 ($\text{t} \cdot \text{ha}^{-1}$), and 529.5 ± 176.8 ($\text{t} \cdot \text{ha}^{-1}$), respectively, demonstrating a rapid increase of biomass from young stand age trees to overmature stand age trees (Table 4). The stem made the largest contribution to total tree biomass. The results of ANOVA showed that the mean value of stem biomass and total tree biomass significantly different among the age classes (Table 4). Moreover, the regression analysis between basal area and biomass revealed strong positive correlation (Table 3, Figure 2). In addition to total tree biomass, we also measured the value of biomass in understory vegetation, deadwood, and litter, and no significant variation was observed among all age classes in their values (Table 4).

3.2. Carbon Stocks. The results show the values of a living tree, understory vegetation, litter, deadwood, and soil carbon of the respective age stands (Table 5). It can be seen from the table that the average living tree carbon varied between 40.0 ± 6.2 ($\text{t} \cdot \text{ha}^{-1}$) and 264.5 ± 88.4 ($\text{t} \cdot \text{ha}^{-1}$), respectively. Among the all age stands, significantly larger value was recorded in the overmature stand, whereas smaller value was recorded in the young age stand. The mean value of carbon in understory vegetation was found the maximum in the mature stand. Similarly, deadwood and litter carbon were recorded higher in the overmature stand and lower in the mature stand. However, no significant variation was found in carbon values of understory vegetation, deadwood, and

TABLE 4: Biomass of Chir Pine forest.

Age group	Mean STBM ($\text{t} \cdot \text{ha}^{-1}$)	Mean TTBM ($\text{t} \cdot \text{ha}^{-1}$)	Mean HLDM ($\text{t} \cdot \text{ha}^{-1}$)	Mean TBM ($\text{t} \cdot \text{ha}^{-1}$)
Young	50.6 ± 7.8 ^C	80.0 ± 12.4 ^C	0.7 ± 0.3	131.3 ^C
Mature	217.1 ± 125.6 ^B	343.1 ± 167.6 ^B	0.9 ± 0.3	561.1 ^B
Overmature	335.1 ± 126.3 ^A	529.5 ± 176.8 ^A	1.0 ± 1	865.1 ^A
Mean	200.9	338.3	0.86	519.1

Superscripts in each column show significant differences at $\alpha=0.1$ and $p \leq 0.0001$. STBM = stem biomass; TTBM = total tree biomass; HLDM = herb, litter, and deadwood biomass; TBM = total biomass; TBM = STBM + TTBM + HLDM.

litter in all age stands. Soil organic carbon analysis showed that young stand holds the maximum soil carbon and the overmature stand holds minimum carbon. The results showed a decreasing trend from young to overmature stand in soil carbon (see Figure 3).

4. Discussion

The present findings showed that stem density of Chir Pine in all age stands decreases with increasing diameter. In Chir Pine forest, not only natural thinning is common, but stem removal under the shelterwood system is also practiced which are mostly concentrated in the mature and overmature age class [22]. Those areas of the forest where

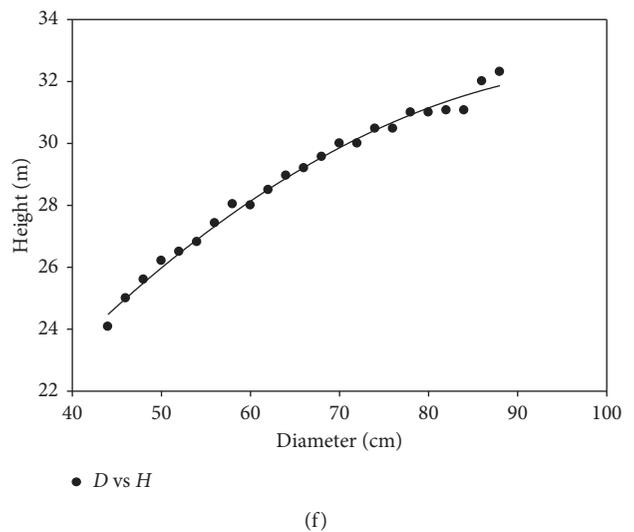
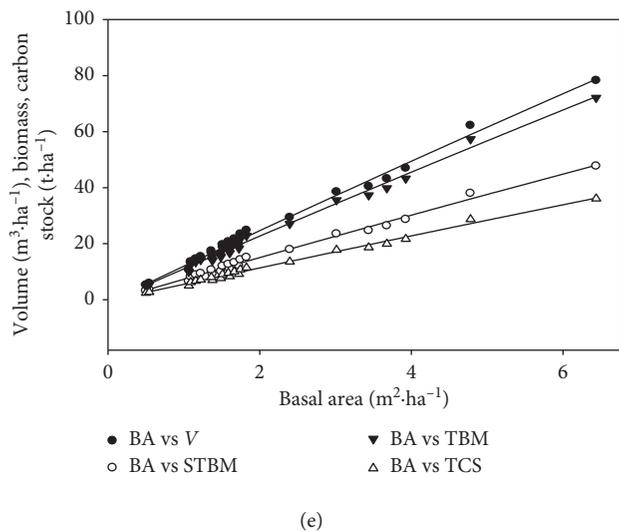
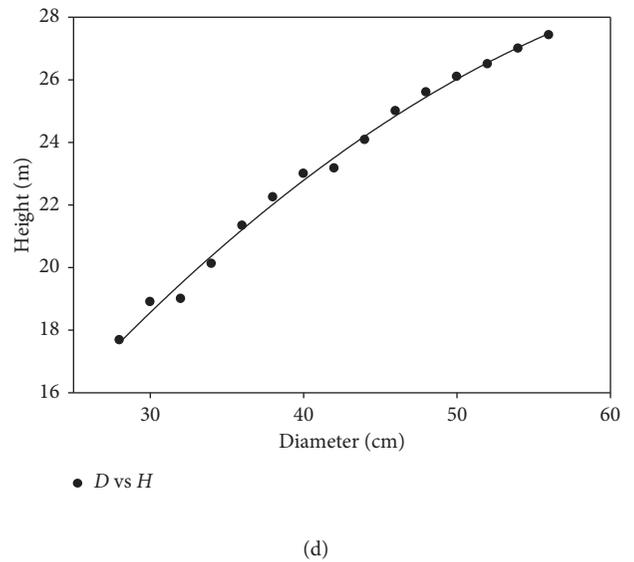
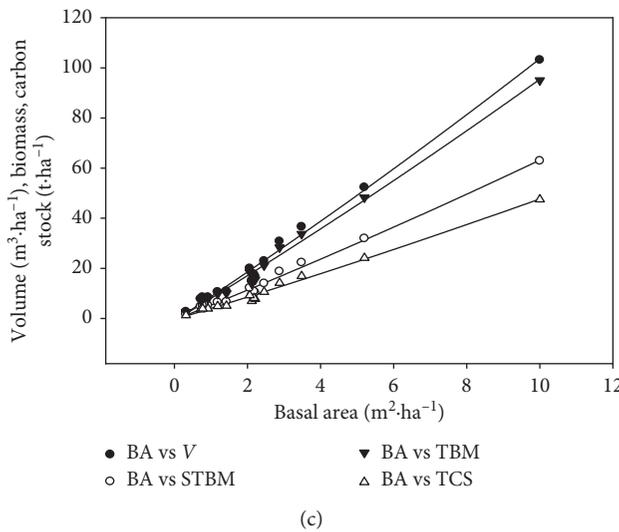
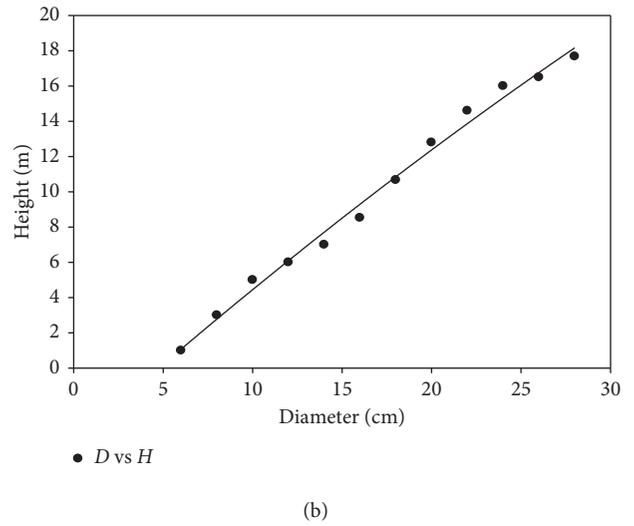
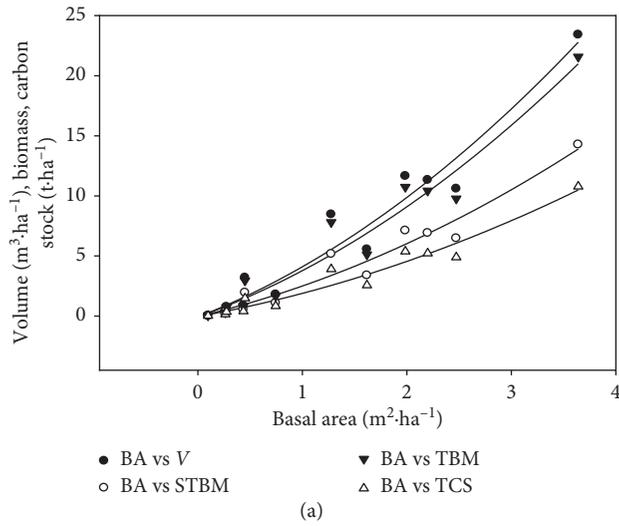


FIGURE 2: Relationship between D and H , BA , and V , $STBM$, TBM , TCS in the young (a, b), mature (c, d), and overmature (e, f). D =diameter (cm), H =height (m), BA =basal area ($m^2 \cdot ha^{-1}$), V =volume ($m^3 \cdot ha^{-1}$), $STBM$ =stem biomass (t/ha), TBM =total biomass (t/ha), TCS =total carbon stock ($t \cdot ha^{-1}$).

TABLE 5: Carbon stocks of Chir Pine forest.

Age group	Mean LTC (t·ha ⁻¹)	Mean HLD (t·ha ⁻¹)	Mean SC (t·ha ⁻¹)	Mean TC (t·ha ⁻¹)
Young	40.0 ± 6.2 ^C	0.3 ± 0.15 ^A	50.0 ± 11.8 ^A	90.3 ^C
Mature	171.5 ± 83.5 ^B	0.4 ± 0.1 ^A	46.2 ± 15.7 ^A	218.1 ^B
Over mature	264.5 ± 88.4 ^A	0.4 ± 0.45 ^A	44.4 ± 9.1 ^A	309.5 ^A
Mean	158.6	0.36	46.9	205.9

Superscripts in each column show significant differences at $\alpha=0.1$ and $p \leq 0.0001$. LTC=living tree carbon; HLDC=herb, litter, and deadwood carbon; SC=soil carbon; TC=total carbon; TC=LTC+ HLDC + SC.

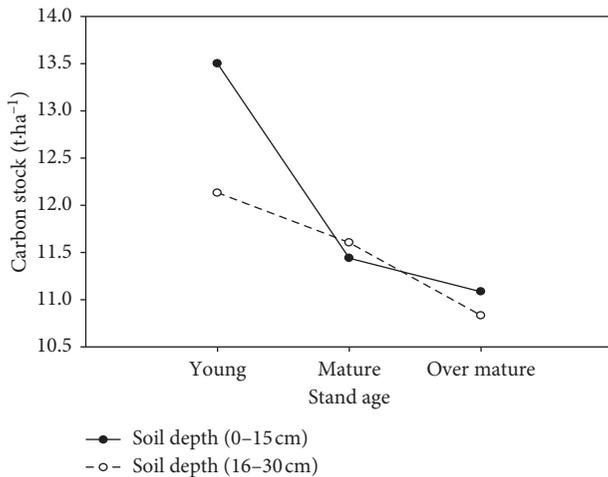


FIGURE 3: Soil carbon stock in young, mature, and overmature stand at 0–15 cm and 15–30 cm depth increment.

thinning and felling operations are completed were then allocated to the young age class, and consequently 72% regeneration potential was recorded in the young stand. This also resulted in lower stem volume and stem biomass in young age class as compared to old age stands. The results further demonstrated that Chir Pine biomass carbon in living tree increased steadily with age stand. These findings are consistent with [6, 19, 40, 41], confirming that stand age is the important variable in biomass carbon estimation. However, the mean values of understory vegetation (USV) and deadwood carbon showed contrasting pattern against the living tree biomass carbon. The USV biomass carbon was recorded higher in the mature stand as compared to young stand and overmature stand. This can be attributed to management operations in the forest. It has been discussed earlier that Chir forest in Pakistan is managed under shelterwood system. Under this system, the young crops received the cleaning, and clearing operations hence resulted in lower biomass carbon values. Similarly, in overmature stand heavy thinning, regeneration felling and final felling operations are carried out that may affect the biomass carbon of USV. In contrast, the mature block receives mostly the thinning and selected felling operations. This creates canopy gaps, thus providing a favorable condition for the growth of USV. Consequently, it gives the larger value of biomass carbon.

The biomass carbon of deadwood was found higher in the overmature block. This higher value of biomass carbon in overmature block reflects the effect of management operations. In the mature block, due to felling operation, the

accumulation of more wood materials on forest floor resulted in higher deadwood carbon. The previous results also reported that biomass carbon for conifer chronosequence increases with stand age [42–44], and some researches showed that the carbon stock of forest floor and understory vegetation decreased with increasing stand age [8, 19] because of high susceptibility to disturbances, variation, and decomposition rate in stand age [6, 8, 45]. The results of our soil carbon analysis showed decreasing trend with respect to age. This decreasing trend in soil may be attributed to the soil disturbance during the felling operations in the overmature stand and decrease in the natural thinning with the stand age. The soil organic carbon has many limitations that whether or not soil organic carbon stock could change with respect to stand ages [46, 47]. Some previous studies showed that there is no significant increase in soil organic carbon stock with stand age [46, 17], while some other previous studies showed increasing of soil organic carbon with increasing stand age [45, 47, 48]. The difference may due to different factors such as climatic factor, soil factor, and forest type [6], but in case of the present study, the lower soil carbon with respect to increasing stand age is the result of management operations such as thinning and felling. During these operations, the soil becomes disturbed and the top layer gets exposed to wind and rainfall that wash out the surface soil, reducing the soil organic matter and soil carbon. However, generally, soil organic carbon increases with stand age in conifer forest, due to the accumulation of organic matter in older stages [14, 40].

In conclusion, our results depicted that the biomass carbon of living tree (LT) increases with stand age. However, the value of soil carbon, deadwood, and USV carbon did not follow the same trend. Altogether, our current findings figure out that the mean carbon values of all components varied between 90.3 t·C·ha⁻¹ in young, 218.1 t·C·ha⁻¹ in mature, and 309.5 t·C·ha⁻¹ in the overmature stand. These results indicated the significant increasing trend in carbon stocks with stand age. These present results highlighted the importance of age in assessing carbon measurement of a forest. Furthermore, our results showed the effects of management operations on the forest floor and soil carbon. The lower soil carbon value in the overmature stand is the result of soil disturbances during management operations.

5. Limitations and Uncertainties

This study was conducted using the field inventory method to explore patterns of biomass and carbon allocation across Chronosequence of Chir Pine (*Pinus roxburghii*) forest in Pakistan. We calculate the stem biomass from stem volume

and wood density and then converted stem biomass to total tree (above ground) biomass using a fixed generic BEF value of 1.51 following Haripriya [30], IPCC [31], and Nizami [22]. For measuring the belowground biomass carbon, we used a root to shoot ration (R) of 0.19 following Rana et al. [32]. As the BEF and R value may vary with stand age, the present estimates of carbon allocation along the Chronosequence may contain some uncertainties, which might induce errors in carbon stock estimation along the stand age.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

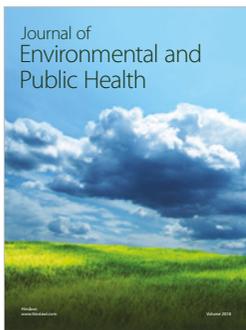
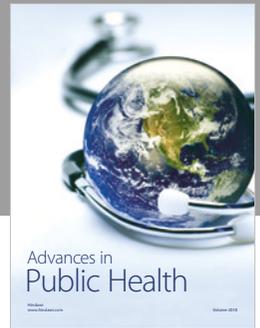
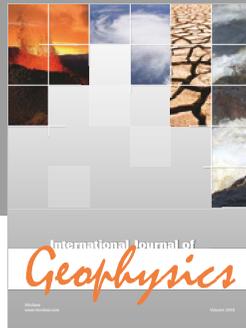
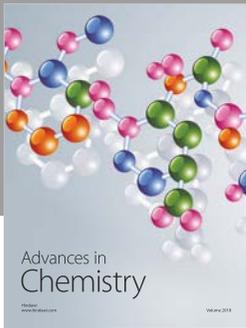
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