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THE BELA FOREST ECOSYSTEM OF DISTRICT JHELUM, A POTENTIAL CARBON SINK

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Abstract

The present study was carried out in the Bela forest of District Jhelum (Punjab). The study was aimed to estimate the growing stock, biomass and carbon stock of the Bela plantation. Carbon stock in the Bela plantation was assessed in the Upperstory vegetation, understorey vegetation and in soil. The major tree species in the Bela plantation of the study site were *Eucalyptus camaldulensis* (EC), *Dalbergia sissoo* (DS), *Broussonetia papyrifera* (BP), *Morus alba* (MA) and *Acacia modesta* (AM). The results of the present study reveled that specie wise stem density ranges from 8±1 to 274±3 trees ha^{-1} while the mean stem density was 691±13 trees ha^{-1}. The mean height of the trees were in the ranged of 9.51±0.98 m (*Morus alba*) to 18.97±2.48m (*Eucalyptus camaldulensis*). The value of basal area ranges from 0.22±0.01 m^2 ha^{-1} to 18.17±0.28 m^2 ha^{-1}. The average recorded stem volume was 278.92±7.41 m^3 ha^{-1}. The total tree biomass varied between 0.71±0.05 t ha-^{1} to 176.31±3.19 t ha-^{1}. The total calculated biomass in the shrubs and grasses was 4.93±2.7 t ha-^{1} while the recorded total carbon stock in the shrubs and grasses was 2.45±1.35 t ha-^{1}. Average soil carbon stock was determined as 30.19 ±12.10 t ha-^{1} in the study area. Over all the Bela forest of the study site stored about 198.18±18 t ha^{-1} of carbon. Among the different carbon pools the maximum carbon was stored by the Upper storey vegetation biomass (83.53%) fallowed by soil (15.23%) while the minimum carbon stock was stored in Understory vegetation biomass (1.23%).

Key words: Bela forest, Growing stock, Carbon stock, Carbon pools.

Introduction

Global Climate change is the burning issue among the scientific community around the globe. The increases emissions of green house gases due to manmade activities are the responsible factors for the global climate change. Carbon dioxide is one of the major green house gas. The increasing level of carbon dioxide due to industrial revolution leads significant influences on our climate (Malhi *et al*., 1999; Sharma *et al*., 2010). Forest ecosystem is the important component of global carbon cycle. The Kyoto protocol of the UNFCCC recognizes the forest, a potential source for the mitigation and stabilization of the increase level of CO_2 in the atmosphere (Masera *et al*., 2003; Tobin & Nieuwenhusis, 2007; Sohail *et al*., 2014).

Among terrestrial ecosystems, forest ecosystem store largest amount of carbon (Anon., 2001; Anon., 1984, Adnan *et al*., 2014). Forests have the capacity to store 20 to 50 times more carbon compared to other land uses (Houghton & Heckler, 1995). Forest acts as a storage factory of carbon and among the terrestrial ecosystem forest has the significant ability to mitigate global climate change (Gairola *et al*., 2011; Sharma *et al*., 2010).

Forest plantations have a little input to the entire balance of terrestrial carbon (3.8% of the world's entire forest area; Anon., 2006) but their potential to take in and store carbon has been acknowledged to play a more significant responsibility in climate change mitigation (Canadell *et al*., 2007). Relevant scientific information allows accurate evaluation of all these benefits, help in the progress of satisfactory policies for climate change mitigation (Anon., 2007).

In Pakistan, provincial forest departments of respective provinces prepare their forests working plans by conducting forest inventories. But there is lack of literature regarding carbon stocks in available forest resources. Similarly, no relevant study has been conducted regarding carbon stock of riverain forest of Pakistan. The present study was carried out in the riverain forest of district Jhelum Punjab, Pakistan to assess the carbon stock of riverain forest. The objectives of the study were; to assess biomass of riverain forests of Jhelum district and to assess carbon stocks of riverain forests.

Materials and Methods

Study area: The present study was conducted in district Jhelum of the Punjab province located at 32°56′ N and 73°44′ E. The average elevation of the area is 250 meters above mean sea level. The total area of riverain forest in the district is 475 hectare. Average annual rainfall is about 850 mm. The temperature ranges from 7.93°C to 42.41°C. The major tree species of the riverain forests of Jhelum are *Eucalyptus camaldulensis*, *Dalbergia sissoo*, *Broussonetia papyrifera*, *Morus Alba* and *Acacia modesta*. Some parts adjacent to the river Jhelum are mostly formed of alluvial deposits with pebble beds often several hundreds of feet in thickness. The soil consists of pebbles or gravel mixed with clay deposits.

Research design and data collection: Twenty plots of 0.1 ha were established in the entire study area. The plots were circular in shape having radius of 17.84 m. The established plots were representative of the entire study area. A sub plot of 4 m^2 for shrubs and 1 m^2 for herbs and grasses were laid out. Soil samples were collected at depth of 0-15 cm and 16 to 30 cm in each plot for soil carbon estimation. For collection of the required information for growing stock, biomass and carbon stock asseseement, diameter at breast height (DBH) for each tree was calculated by means of diameter tape and caliper in every sample plot. Abney's level and Haga altimeter were used for measurement of tree height. The under storey vegetation was destructively harvested within the 4 m^2 and 1 m^2 sub plot for herbs and grasses.

Growing stock and biomass estimation: Volume of tree (m^3) was determined by using the following formula of (Philips, 1994).

$$\text{Tree volume } (m^3) = (\pi/4) \times d^2 \times h \times f)$$

where, h= Height d= Diameter at breast height (dbh) and f= Form factor

Stem biomass was calculated from the wood density (kg m^{-3}) of the relevant trees and volume (m^3) by using the following relation:

$$\text{Biomass (kg)} = \text{Basic wood density (kg } m^{-3}) \times \text{Volume } (m^3)$$

The leaves, branches, twig, and roots contribution in overall biomass was estimated by using biomass expansion factor (BEF) of the respective tree species. The BEF of the each species was sourced from available literature (Haripriya, 2000; Anon., 2006).

Measurements of understorey vegetation biomass: The shrubs, herbs, and grasses were collected from each sample plot. The fresh weight of the all samples (kg) (shrubs, herbs, and grasses) was recorded and the average weight was taken and extrapolated to calculate contemporary weight of the whole plot. Fresh weight of one kg sample was labeled in bag and transferred to laboratory. The collected samples were dried at 72°C for 48 hours (Roy *et al*., 2001; Brown & logo, 1992). The dried sample weight was recorded in kg and biomass was determined as their dry weight (kg)

Calculation of carbon stocks: The carbon stock in the vegetation was estimated by multiflying total biomass (t ha^{-1})with the conversion factor (0.5) that has been globally used for the measurement of carbon stock ((Roy *et al*., 2001; Brown & Lugo, 1982; Malhi *et al*., 2004; Nizami, 2012; Adnan *et al*., 2014; Adnan & Nizami, 2015).

Calculation of soil carbon: Three soil Samples were collected from each plot of 0.1 ha at a depth of 0-15 cm and 16 – 30 cm by means of soil auger and soil cores of identified volume of 198.24 cm^3(diameter =5.9 cm and height =7.25 cm). In the field, weight (gm) of each soil sample was measured and place in the labeled bags and were brought to laboratory for further analysis. The bulk density (gm cm-^{3}) of each soil sample was measured. Oxidizable organic carbon method of (Walkley & Black, 1934) was used for the determination of soil carbon. The soil carbon in t ha-^{1} was determined by using the following formula (Persion *et al*., 2008).

$$\text{Soil carbon t ha}^{-1} = \text{Soil Bulk density (gm/cm}^3) \times \text{SOC (\%)} \times \text{Thickness of horizon (cm)} \times 100$$

Calculation of total carbon stock: The total carbon stocks in Bela forest ecosystem (t ha-^{1}) was calculated by adding the total carbon stored in the upperstorey vegetation, understorey vegetation and carbon stored in soil.

Results and Discussions

Growing stock: The dominant trees species of the Bela forest of the study site were *Eucalyptus camaldulensis* (EC), *Dalbergia sissoo* (DS), *Broussonetia papyrifera* (BP), *Morus alba* (MA) and *Acacia modesta* (AM). The Stem density (ha-^{1}) tree height (m) basal area (m^2 ha-^{1}) and stem volume (m^2 ha-^{1}) for each tree species was determined details of which is presented in Table 1. The results of the table shows that density ranges from 274±3 to 8±1 trees ha^{-1}, while the total calculated stem density was 691±13 trees ha^{-1}. The mean height of the trees were in the ranged of 9.51±0.98 m (MA) to18.97±2.48m (EC). The value of basal area ranges from 0.22±0.01 m^2 ha^{-1} to 18.17±0.28 m^2 ha^{-1}. The average recorded stem volume was 278.92±7.41 m^3 ha^{-1}. Among the all trees species the highest volume was recorded for EC. In order to study the relationship between stem diameter (cm) and stem density(ha^{-1}), stem diameter (cm) and tree height (m), basal area (m^2 ha^{-1}) and stem volume (m^3 ha^{-1}) regression models were developed details of which is given in Table 1 and Figs. 1 to 15. Table 2 also showing the results of the relationship type, equations and the value of R^2 between stem diameter (cm) and stem density(ha^{-1}), stem diameter (cm) and tree height (m), basal area (m^2 ha^{-1}) and stem volume (m^3 ha^{-1}).

Upper storey vegetation biomass and carbon stock: Stem biomass in all species was determined from basic wood density (Kg m^{-3}) and volume (m^3 ha-^{1}) of the respective trees species. The maximum average stem biomass was recorded in *Eucalyptus camaldulensis* and was 110.89±2.01 (t ha-^{1}) at basal area of 18.17±0.28 m^2 ha-^{1} while the minimum stem biomass of 0.45±0.03 (t ha-^{1}) at basal area of 0.1460 ± m^2 ha-^{1} was recorded in *Morus alba*. Over all the mean stem biomass in the Bela plantation was 208.39±5.72 t ha-^{1}. For the all trees species regression models were developed to study the relationship between basal area (m^2 ha-^{1}) and stem biomass (t ha $^{-1}$). The relationships are described in Figs. 16-20. The relationship between basal area (m^2 ha-^{1}) and stem biomass (t ha $^{-1}$) are Polynomial quadratic for all tress species. The total tree biomass varied between 0.71±0.05 t ha-^{1} to 176.31±3.19 t ha-^{1} (Table 3) while the average carbon stock was calculated as 165.54±4.55 t ha-^{1}.

Biomass and carbon stock in under story vegetation (shrubs and grasses): The mean biomass of shrubs was 3.35±1.92 t ha-^{1}. The maximum biomass was 6.37 t ha-^{1} while the minimum biomass was 0.90 t ha-^{1}. The mean biomass in grasses was 1.58±0.78 t ha-^{1}. The total calculated biomass in the shrubs and grasses was 4.93±2.7 t ha-^{1} while the recorded total carbon stock in the shrubs and grasses was 2.45±1.35 t ha-^{1}.

Determination of soil carbon (t ha^{-1}): The mean soil carbon was determined from the relation of total organic matter (%), depth of horizon and soil bulk density gm /cm^3. Average soil carbon stock was determined as 30.19 ± 12.10 t ha-^{1} in the study area. The maximum carbon stock of 54.11 t ha^{-1} was recorded in one plot, where the minimum carbon stock of 15.10 t ha-^{1} was recorded in one plot.

Table 1. Density (ha^{-1}) tree height (m) basal area (m^2ha^{-1}) and stem volume (m^3ha^{-1}).

Species	Density ha^{-1}	Height (m)	Basal area (m2 ha^{-1})	Stem volume m^3 ha^{-1}
Eucalyptus camaldulensis (EC)	226 ± 4	18.97 ± 2.48	18.17 ± 0.28	156.18 ± 2.83
Dalbergia sissoo (DS)	274 ± 3	11.48 ± 2.21	13.36 ± 0.44	78.13 ± 3.30
Broussonetia papyrifera (BP)	168 ± 3	9.76 ± 1.71	7.95 ± 0.19	42.84 ± 1.20
Morus alba (MA)	15 ± 2	9.51 ± 0.98	0.14 ± 0.12	0.65 ± 0.04
Acacia modesta (AM)	8 ± 1	9.92 ± 0.95	0.22 ± 0.01	1.12 ± 0.04
Total	691 ± 13		39.84 ± 1.04	278.92 ± 7.41

Table 2. Relationship type, equation and R^2 for the respective tree species.

Specie	Relationship type	Equation	r^2
	1 Polynomial linear	y= 21.8933-0.3320*x	0.9901
Eucalyptus camaldulensis	2 Polynomial quadratic	y= 8.3877+0.4544*x-0.0038*x^2	0.9945
	3 Polynomial quadratic	y= -1.5608+11.1654*x-0.7455*x^2	0.9913
	1 Polynomial cubic	y= 57.8262-3.7748*x+0.1483*x^2-0.0021*x^3	0.9908
Dalbergia sissoo	2 Polynomial linear	y= 3.7962+0.3076*x	0.9990
	3 Polynomial quadratic	y= 0.1431+3.3130*x+1.8800*x^2	0.9970
	1 Polynomial linear	y= 18.6127-0.3358*x	0.9800
Broussonetia papyrifera	2 Polynomial quadratic	y= 2.7893+0.4070*x-0.0047*x^2	0.9907
	3 Polynomial quadratic	y= -0.1409+5.0499*x+1.1624*x^2	0.9930
	1 Polynomial cubic	y= -33.2143+11.3393*x1.0714*x^2+0.0312*x^3	0.9643
Morus alba	2 Polynomial quadratic	y= -1.2871+1.5896*x-0.0545*x^2	0.9859
	3 Polynomial quadratic	y= 0.0590-0.8069*x+102.8817*x^2	0.9986
	1 Polynomial quadratic	y= 27.6000-2.3929*x+0.0536*x^2	0.9821
Acacia modesta	2 Polynomial linear	y= 3.9080+0.3010*x	0.9995
	3 Polynomial quadratic	y= -0.1291+11.7542*x-82.4888*x^2	0.9853

1, 2, 3= Relationship between diameter (cm) and density (ha-1), Diameter (cm) and height (m) basal area m2 ha-1) and volume (m3 ha-1)

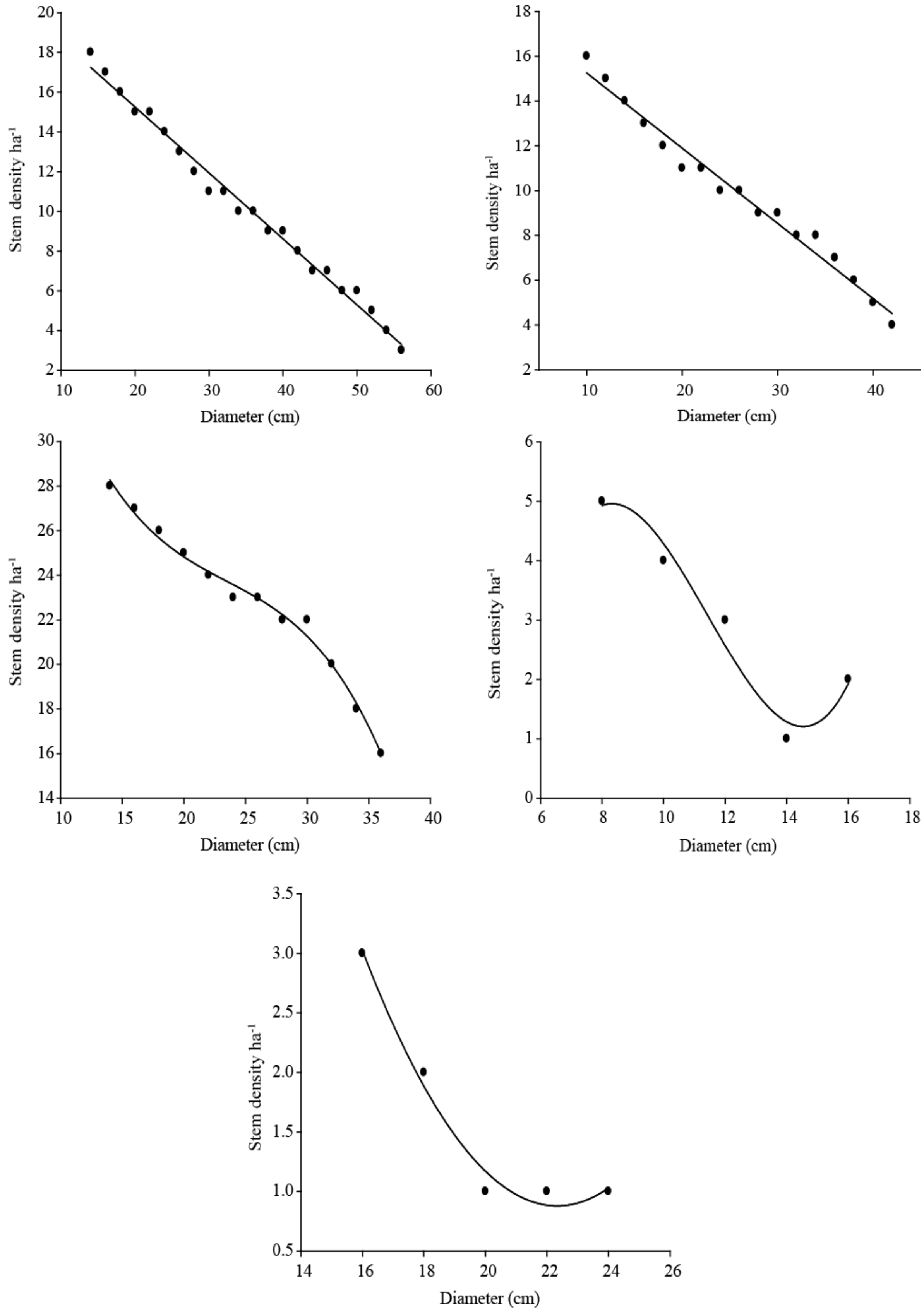
Table 3. Biomass (t ha^{-1}) and carbon stock (t ha^{-1}).

Species	Stem biomass t ha^{-1}	T. tree biomass t ha^{-1}	c. stock t ha^{-1}
Eucalyptus camaldulensis	110.89 ± 2.01	176.31 ± 3.19	88.15 ± 1.59
Dalbergia sissoo	66.41 ± 2.81	105.90 ± 4.47	52.79 ± 2.23
Broussonetia papyrifera	29.56 ± 0.83	47 ± 1.32	23.50 ± 0.66
Morus alba	0.45 ± 0.03	0.71 ± 0.05	0.35 ± 0.02
Acacia modesta	1.08 ± 0.04	1.71 ± 0.07	0.85 ± 0.03
Total	208.39 ± 5.72	331.09 ± 9.1	165.54 ± 4.55

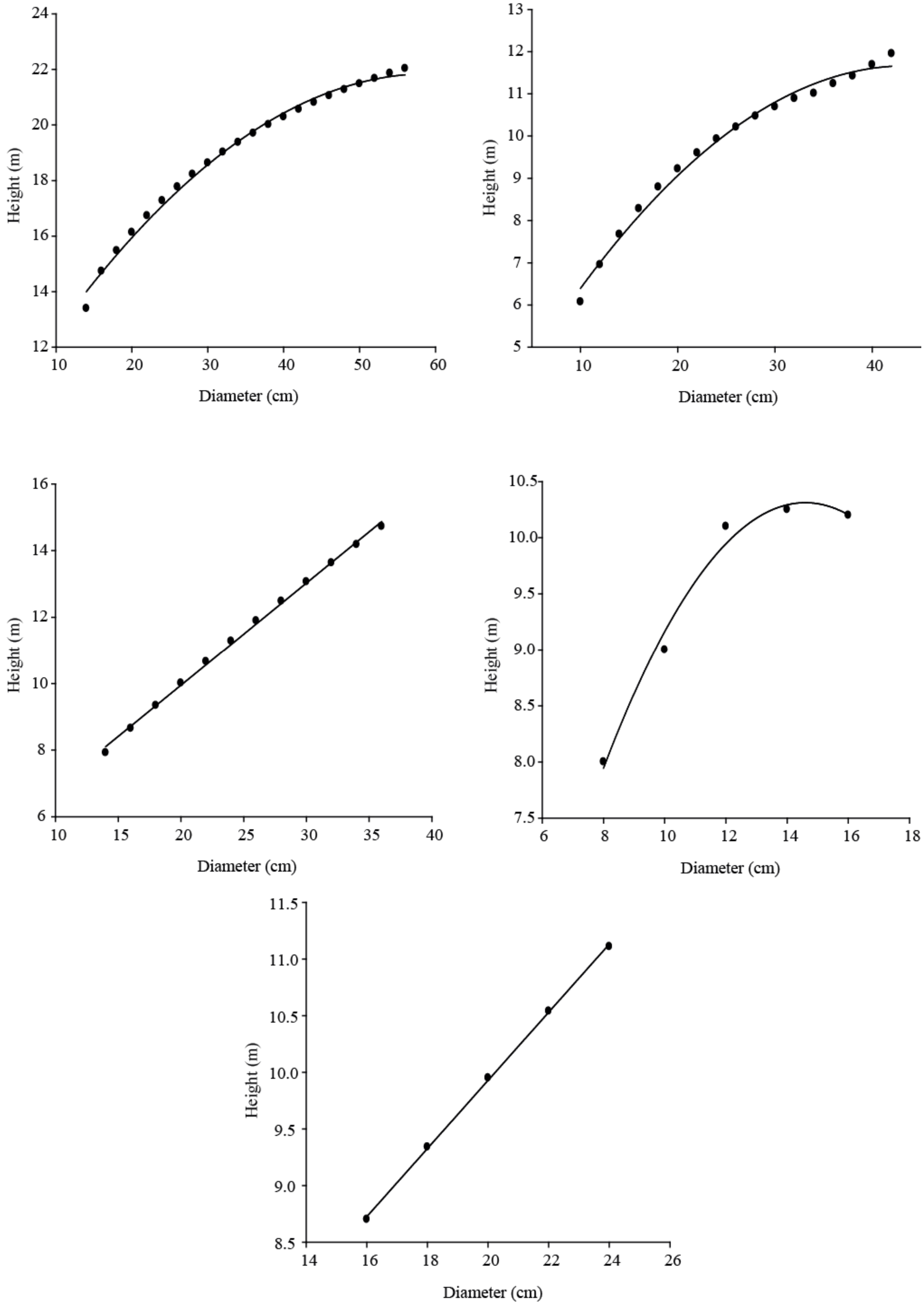
Table 4. Total carbon stock t ha^{-1} in the respective carbon pools.

S. No.	Carbon pools	Total carbon stock t ha^{-1}	Percentage
1.	Upper storey vegetation biomass	165.54 ± 4.55	83.53
2.	Understory vegetation biomass	2.45 ± 1.35	15.23
3.	Soil carbon	30.19 ± 12.10	1.24
	Total	198.18 ± 18	100

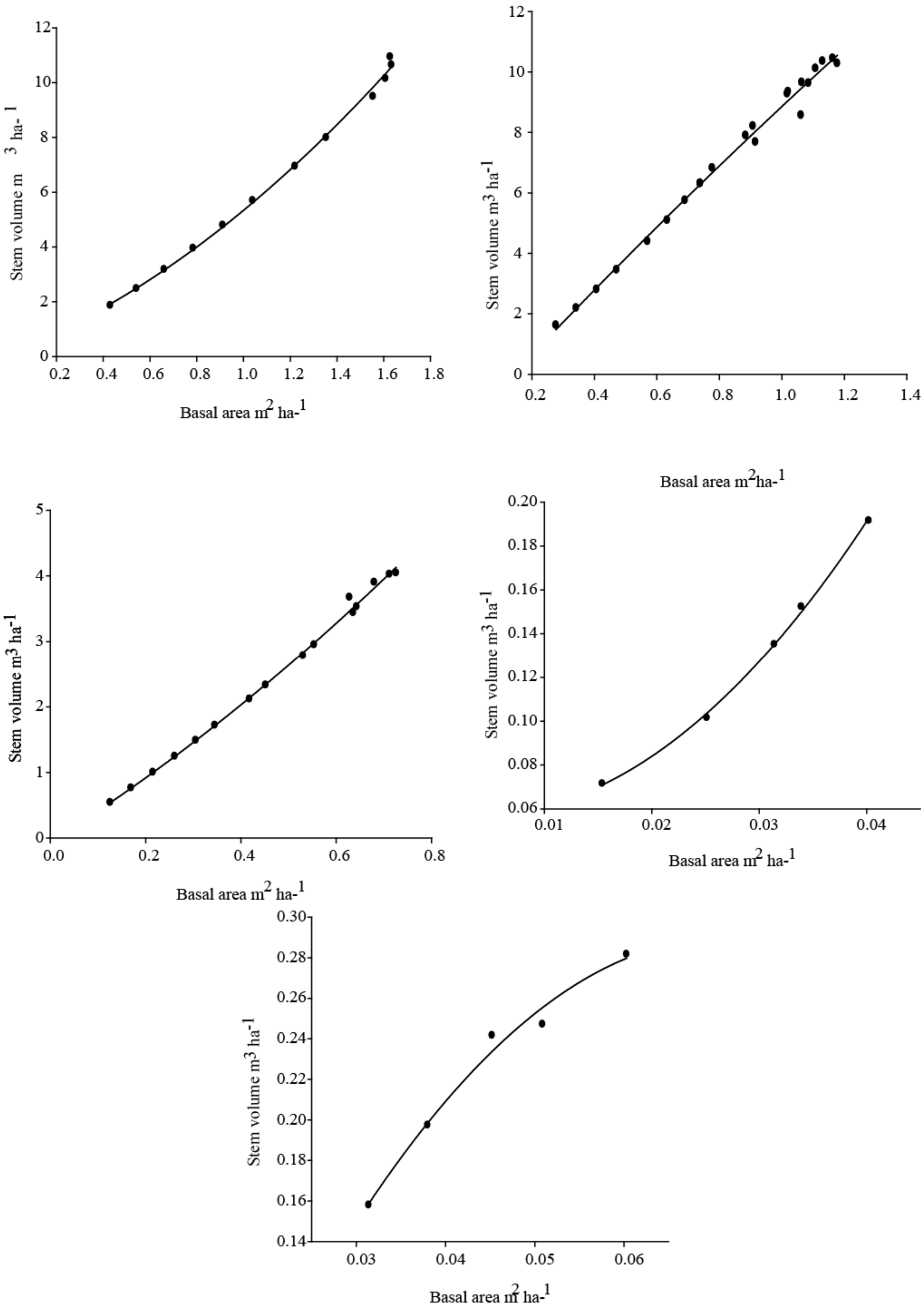
Determination of total carbon stock (t ha^{-1}): The total carbon stock (t ha^{-1}) was determined by totaling the quantity of carbon existing in the respective carbon pools. The carbon stock in present study was determined in Upper storey vegetation biomass, Understory vegetation biomass and soil carbon. The results of the total carbon stock of the Bela forest ecosystem are given in Table 4. It can be seen from the table that the total carbon stock ranged from 2.45±1.35 t ha^{-1} in Understorey vegetation biomass to 165.54±4.55 t ha^{-1} in Uppe storey vegetation biomass while the total stored carbon in soil was 30.19 ± 12.10 t ha^{-1}. Table 4 also described the percentage contribution of different carbon pools in the total carbon stock of the ecosystem. Over all the Bela forest of the study site stored about 198.18±18 t ha^{-1}. Among the different carbon pools the maximum carbon was stored by the Upper storey vegetation biomass (83.53%) fallowed by soil (15.23%) while the minimum carbon stock was found in Understorey vegetation biomass (1.23%).



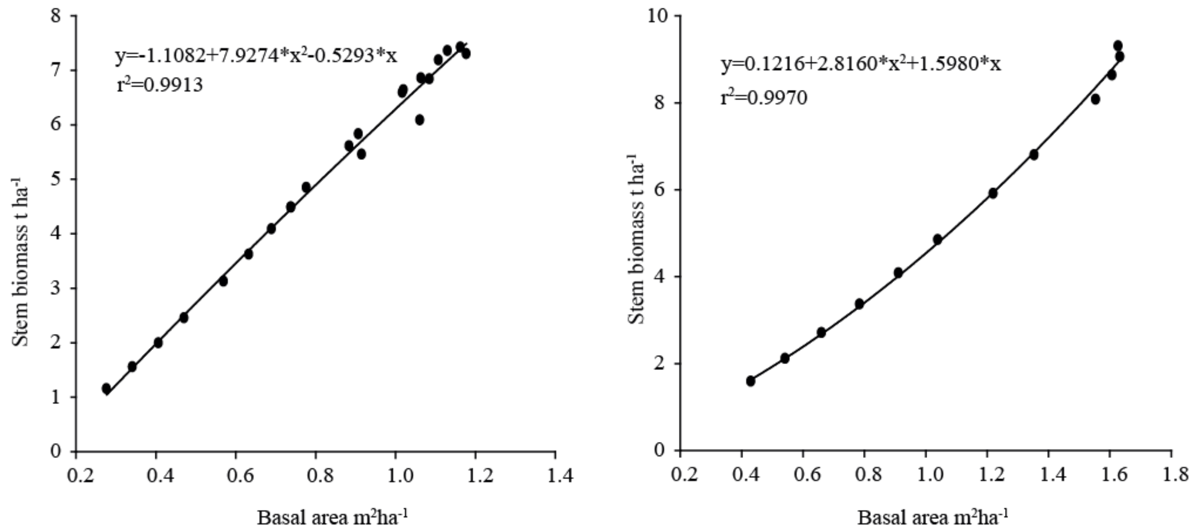
Figs. 1-5. Relationship between diameter (cm) and stem density ha^{-1} in EC, DS, BP,MA and AM respectively.



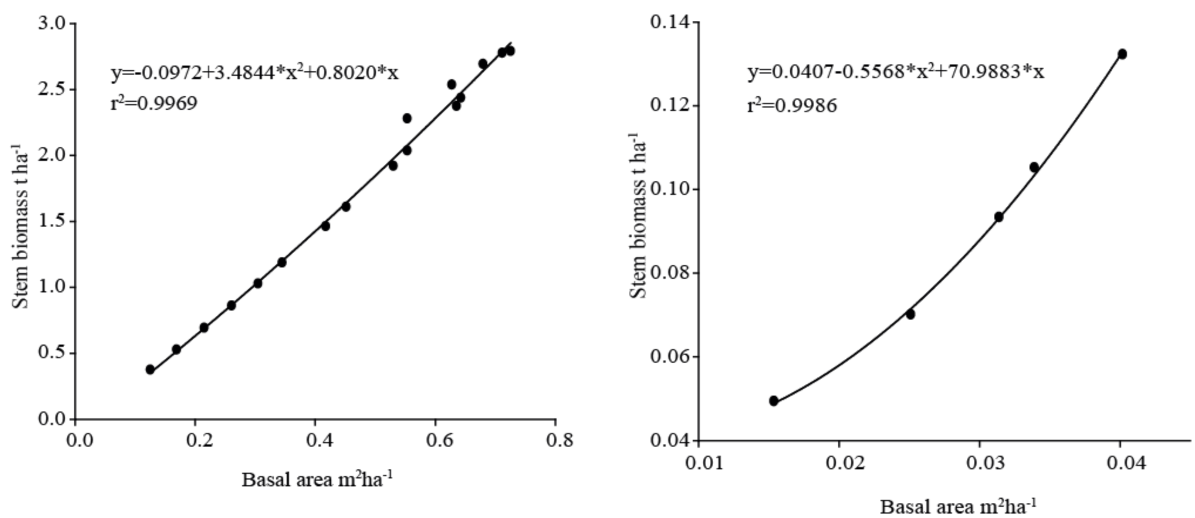
Figs. 6-10. Relationship between diameter (cm) and height (m) in EC, DS, BP, MA and AM and



Figs.11-15. Relationship between basal area and stem volume in EC, DS, BP, MA and AM.



Figs. 16-17. Relationship between Basal area (m^2 ha^{-1}) and stem biomass (t ha^{-1}) in *Eucalyptus camaldulensis* and *Dalbergia sissoo* respectively.



Figs. 18-19. Relationship between Basal area (m^2 ha^{-1}) and stem biomass (t ha^{-1}) in *Broussonetia papyrifera* and *Morus alba* respectively.

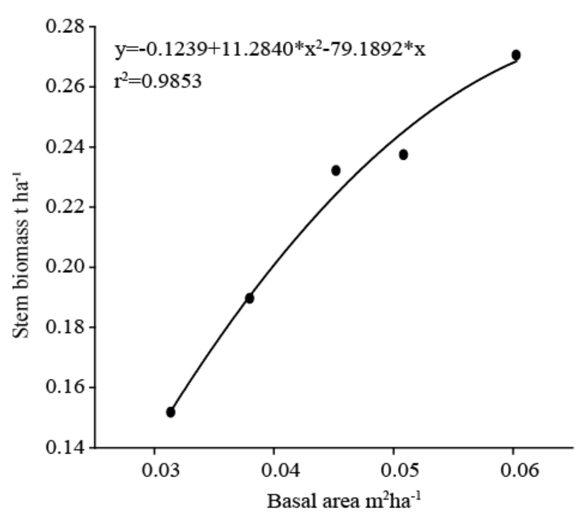


Fig. 20. Relationship between Basal area (m^2 ha^{-1}) and stem biomass (t ha^{-1}) in Acacia modesta.

Discussions

Around the globe forest and trees are planted for multiple purposes, forest plantation accounts for about 7% of the total forest area (264 million ha) and from 2000 to 2010 the area of planted forest expand at the rate of 5 million ha per year. Forest plantation has been considered a potential carbon sink and a mitigation option for the climate change. The Bela forest lies in the providence of Sindh and Punjab along the river banks. The total area of Bela forest in Pakistan is about 271000 ha (Bajwa, 2012).

The assessment of biomass and carbon stock in a forest, based on growing stock are the reliable source (Haripriya, 2000; Tolunaly, 2009; Chhabara *et al*., 2002; Walle *et al*., 2005; Adnan *et al*., 2014). In present study the biomass and carbon stock of the Bela forest was assessed through inventory. In present study it was found that stem density (ha^{-1}) decreases with increases in diameter (cm) for all tree species (Figs. 1-5). The value of R^2 between stem density (ha^{-1}) and diameter (cm) ranges from 0.96 to 0.99 that showed a very strong relation between stem diameter (cm) and density (ha^{-1}). Similar relationship between stem diameter (cm) and stem density (ha^{-1}) were reported by (Nizami, 2012, Raqeeb *et al*., 2014). The height (m) of tree increases with increase in the diameter (cm) of tree (Nizami 2012, Sohail *et al*., 2014). In present study it was found that for all tree species the height (m) of tree increases with increase in the diameter (cm) (Fig. 1-5 and Table 2). The value of the R^2 in Table 2 for diameter (cm) and height (m) described a strong relation between diameter (cm) and tree height (m). Stem volume (m^3 ha^{-1}) and stem biomass (t ha^{-1}) are the function of basal area, the value of stem volume (m^3 ha^{-1}) and biomass (t ha^{-1}) have a direct relation with the value of basal area(m^2 ha^{-1}), both stem volume (m^3 ha^{-1}) and stem biomass (t ha^{-1}) increases with increase in basal area (Nizami, 2012, Adnan *et al*., 2014; Adnan & Nizami, 2015). In the present study similar results were recorded for all tree species (Figs. 11-20 Table 2).

In present study the average value of total tree biomass was recorded as 331.09±9.1 t ha^{-1}. This value gives higher estimates from the value of Anon., (2003) of 180 t ha^{-1} for Asia Broadleaf plantation. The reason of this may be that the Anon., (2003) only reported the above ground biomass of the plantation only, while in the present study we reported the above and below ground biomass. Old growth forest stored more carbon because of more tree biomass (Zang *et al*., 2012). Old age trees, with large diameter results more tree biomass and carbon stock (Adnan *et al*., 2014). Similar results were figure out in the present study. In study area the *Eucalyptus camaldulensis* and *Dalbergia sissoo* were the dominant species with more density and large diameter (12 to 56 cm) that resulted more carbon stock of 88.15 ± 1.59 and 52.79±2.23 t ha^{-1}, respectively while the minimum carbon stock (0.71±0.05 to 1.71±0.07 t ha^{-1}) was recorded in the *Morus alba* and *Acacia modesta* because of the presence of small diameter trees (8 to 24 cm) with low density. Soil carbon is one of the major carbon pools in a forest ecosystem. In present study soil carbon was assessed. The mean soil carbon in the Bela forest was 30.19 ± 12.10 t ha^{-1}. Total carbon stock in the plantation was calculated by adding the stored carbon in the upper storey vegetation, under storey vegetation and in soil. The contribution of vegetation (upper storey vegetation, under storey vegetation) in the total carbon stock of the Bela forest was 84.77% while the contribution of soil carbon in the total carbon stock of the Bela forest ecosystem was 15.23%. The contribution of soil carbon is considerable low that may the results of floods in the study area. The floods wash out the top soil layer, as a consequence the organic matter losses and results in low soil carbon.

Conclusion

Globally Forest plantation expanding with a considerable rate. Forest plantation has been considered a significant measure to mitigate future climate change. The present study estimates the total carbon stored in the Bela forest ecosystem. The results of the study confirmed that the Bela forest ecosystem stored 198.18±18 t ha^{-1} of carbon. In the study site floods occurred at regular interval and wash out the top soil layer, that resulted the soil carbon losses. In the study area, a substantial forest area has become under the river, which was once under forest cover. As a consequence forest land is decreasing day by day. Appropriate supervision of forest territory, reforestation of despoiled land, afforestation, control of deforestation and treatment of despoiled land region can increase the potential of the area to sink and store more carbon.

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