Article

Assessment of biomass and carbon stock in temperate forests of Northern Kashmir Himalaya, India

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Abstract
Accurate characterization and estimation of carbon stock in forest ecosystems of temperate region is important to illustrate their potential contribution to global carbon stocks. In the present study, we evaluated the biomass and carbon stock of Gulmarg forest range of northern Kashmir Himalaya, India. In this study, five forest types: *Pinus wallichiana* (PW), *Abies pindrow* (AP), *Cedrus deodara* (CD), *Picea simithiana* (PS) and *Betula utilis* (BU) were selected. The results have revealed that total tree biomass ranged from 319.2±208.5 Mg ha^{-1} in BU forest to 496.7±278.9 Mg ha-^{1} for the CD forest. The results showed that total biomass carbon stock varies from 143.63±93.87 to 228.47±128 Mg C ha^{-1} across all forest types. The study reveals that the variation in the carbon stocks of different forest types is due to the presence of different composition of species, stand area, tree class size and altitude. This study indicates that the species, CD, present in Gulmarg Forest Range, is the most potent species to sequestrate carbon and hence this forest range plays a significant role in reducing carbon emissions from forest degradation and deforestation. It can be suggested that afforestation using CD species will be helpful in mitigating the impact of regional Climate Change.

Keywords Kashmir Himalaya; biomass; carbon stock; broad leaf forest; climate change.

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1 Introduction

Global climate change is undoubtedly one of the major environmental issues at present and extensive international discussions and negotiations are going on worldwide to deal with this problem. Increasing concentration of various greenhouse gases, in particular carbon dioxide (CO_2) levels in the atmosphere due to industries is widely recognized as the leading cause of the climate change in the world (IPCC, 2007; Zhang and Liu, 2012; Zhang and Liu, 2017). In addition, the anthropogenic activities such as forest degradation, deforestation, burning of fossil fuel and forest fire aggravate the global warming (Griffiths and Jarvis, 2004; Zhang and Zhang, 2012; Vashum et al., 2016). About 50% of total CO_2 emitted into the atmosphere remain within the atmosphere itself indicating the presence of existing carbon sinks which account for the rest of the carbon uptake (Pan et al., 2011). Forest ecosystem are deemed to play an immense role in tackling atmospheric CO_2 concentrations by taking part in regional and global carbon cycles containing large part of the carbon stored on earth, in the form of both soil organic matter (SOM) and biomass (Zhou et al., 2006; Dar et al., 2015). Among various carbon pools in forest viz. aboveground biomass, belowground biomass, soil, dead wood and litter, biomass carbon plays crucial role in mitigating climate change (IPCC, 2007). The importance of forests in climate change is interesting because forests act as a source of atmospheric carbon when they are disturbed by natural or anthropogenic causes such as conversion of forests to farmlands, deforestation and forest degradation and become atmospheric carbon sinks during re-growth after disturbance (Thuille and Schulze, 2006). Carbon stock in forest vegetation varies with geographical location, age and plant species of the stand (Somogyi et al., 2007). Under Reducing Emissions from Deforestation and Forest Degradation Plus (REDD +) policy, reducing carbon emissions from deforestation (conversion of forests to land for other use) and forest degradation (decline in canopy cover) in developing countries, sustainable management, protection and conservation of forests and increase of carbon stocks of forest are the suggested measures to minimize the atmospheric greenhouse gas concentrations (UNFCC, 2008; Mandal et al., 2013).

Globally forests occupy about 30% of the land surface and hold 77% of the global carbon pool found in vegetation (Post and Kwon, 2000) and 54% of the total worldwide carbon pool of the terrestrial ecosystems (FAO, 2001). Approximately 80% and 40% of all terrestrial aboveground and belowground carbon respectively is contained by forest biomass (Goodale et al., 2002). 14% of worlds total forest carbon stock is contributed by temperate forests (Pan et al., 2011). Nearly 19% of dense forest vegetation in India is present in Himalayan zone. Forests accumulate more CO_2 than the atmosphere (Prentice et al., 2001) and managing forests to enhance carbon sequestration is one of the possible means of reducing CO_2 concentration in the atmosphere (Smithwick et al., 2002). For determining carbon loss connected with land-use and land-cover changes, biomass estimation serves as critical aspect. For better estimation of the total forest carbon stock, both aboveground biomass and belowground root biomass need to be accounted in (Hamburg, 2000). By using standard methodologies, periodical monitoring and assessment of variation in forest carbon need to be considered both at local and regional levels.

Carbon stock assessment is important to determine the correlation between climate and CO_2 balance. Bali action plan to all elements of Reducing emissions from deforestation and forest degradation (REDD) has accepted by India at Bali in COP 13, which considers the significance of forests in climate change mitigation in developing countries (UNFCC,2008). In India, particularly in Kashmir, few studies on biomass carbon stock in southern region of Kashmir Himalaya have been carried out (Dar and Sundarapandian, 2013). But work on biomass carbon in northern region of Kashmir Himalayas is still lacking. The present study works to figure out assessment of biomass and carbon stock in five major temperate forest types of northern region of Kashmir Himalaya, India. For India, estimation of biomass carbon in present study are important in view of immense data gaps for this region posing greater challenges to collect information on carbon forestry. In addition, the results from this study will contribute to examine the role and significance of Gulmarg forest range in tackling climate change issue.

2 Study Area and Methodology

2.1 Study site

The study area, Gulmarg forest Range is located at Baramullah district in Jammu and Kashmir. It lies in special forest division, Tangmarg of Kashmir Himalaya at an altitude ranging from 2400-4300 m above mean sea level, extended from 34˚ 26' 99" to 34˚ 10' 95" N and 74˚ 75' 75" to 74˚ 51’ 07” E (Fig. 1). The area is mountainous and covered by dense coniferous vegetation. This area has Sub-Mediterranean type climate with annual precipitation of 66-167 cm. The area has moderate summer and severely cold winter receiving moderate to high snow fall during December to February. Main forest types available in the study area includes Group 12/C1 lower western Himalayan temperate forest, Group 13/C3 Himalayan dry temperate forest, Group 14/C1 Himalayan sub alpine forests and Group 15/C3 Himalayan moist alpine forests (Champion and Seth, 1968). Forests of Gulmarg forest range are dominated by conifers with sprinkled broad leaved species. The conifers mainly comprise of *Abies pindrow* (AP), *Pinus wallichiana* (PW), *Picea simithiana* (PS), and *Cedrus deodara* (CD) whereas broad leaved species include *Betula utilis* (BU). Great variation in the forest types with change in altitude is the characteristics of Gulmarg Range of Special Forest Division, Tangmarg. CD either as pure crop or along with PW, occurs mostly on gentle slopes, at an altitude range of 1600-2500 m. PW and CD thrives well together on well drained, light and loamy soils while as PW alone is generally found at lower elevations and thrives well on clayey and stiff soils. AP occupies higher elevation, ranging from 2100-3300 m and extends to alpine zone. AP and PS thrives well in shallow soils on upper hills. BU is dominant and constitutes timber line on high slopes at an altitude range of 2800-3300 m and survives even in extreme cold temperature and violent winds.

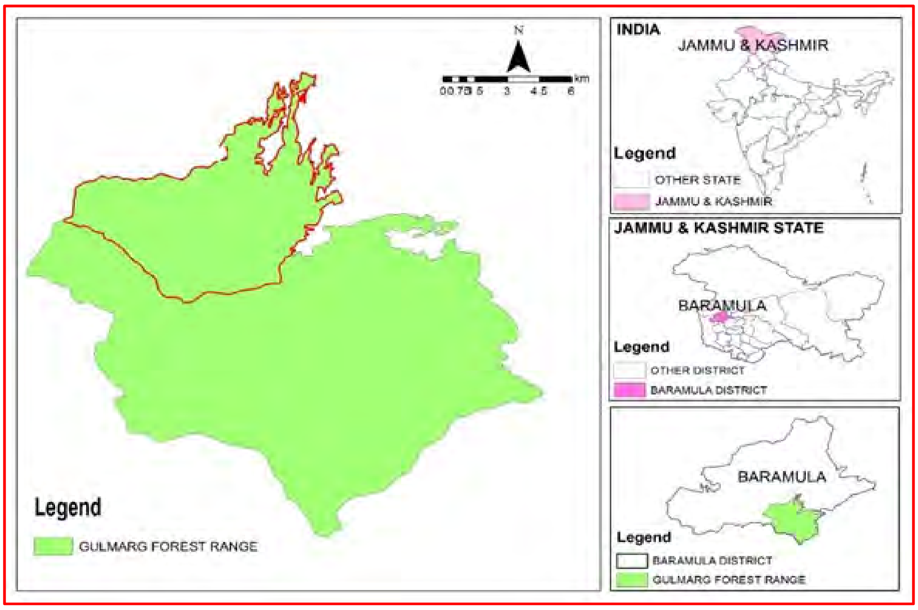

Fig. 1 Location map of study area.

2.2 Pilot survey

Preliminary information about the study area was gathered by reconnaissance survey for developing a scheme of classification. Specific sampling sites were chosen on the basis of vegetation variability by adopting stratified random sampling design. On the basis of the tree species dominance, forest area was divided into five forest types: (i) PW, (ii) CD, (iii) AP, (iv) PS and (v) BU. To determine the variation, simple random sampling was carried out in these forest types for actual ground measurements (Diameter at breast height and tree height). On the basis of variance in ground measurement, number of sampling units was obtained using the formula by Chacko (1965):

$$N = \frac{T^2 \times CV^2}{(SE\%)^2}$$

Where,

N = Number of sample plots

CV = Coefficient of variation

SE% = Standard error percentage (10%) and

T = Statistical value at 95% significance level.

2.2 Field measurements

Field measurements were carried out in the year 2016 (June - October). Sample size was worked out to be 58. For tree measurements, square shaped sample quadrats of 0.1 ha were laid in different types of forest. Tree caliper and Ravi multi-meter were used for the measurement of Diameter at breast height (DBH) and tree height (h) for all the trees respectively. Position of quadrats was recorded by using the hand held global positioning system (GPS). The collected data were thus used for estimation of volume using local as well as regional volume equations depending on the availability for each species published by Forest Survey of India (FSI, 2006). On the basis of calculated volume of stem, biomass was measured by multiplying calculated volume with specific gravity (Singh et al., 2012). Temperate tree species present in India were used for investigation of Biomass Expansion Factor (BEF). Entire forest biomass was determined by using BEF (FRI, 1996).

Belowground biomass (BGB) for each forest type was calculated by using a factor of 0.26 as recommended by Cairns et al. (1997) which is near to the ratio recommended for temperate coniferous forests (Wani et al., 2015).

For the determination of total carbon stock in aboveground and belowground vegetation of the conifers and broad leaved forest types, the total plant biomass was multiplied with convertible factor of 0.46 and 0.45 respectively representing average plant biomass carbon content. (Manhas et al., 2006).

3 Results

3.1 Species diversity, stem density and basal area

Forest-wise values of diversity, stem density and basal area of Gulmarg forest range are given in Table 1. Density varied between 416.66±175.1 ha^{-1} in CD forest type to 866.67±577.7 ha^{-1} in BU forest type, whereas Shannon-Wiener diversity index ranged between 0.13 (BU) and 0.81 (AP) respectively. Highest basal area was observed in AP forest type (78.98±57.13 m^2 ha^{-1}) and lowest in BU forest (33.36±25.09 m^2 ha^{-1}). Evenness index values ranged between 0.19 at BU forest type to 0.46 at AP forest type.

The occurrence of tree species and their Importance Value Index (IVI) in different forest types of Gulmarg forest range are shown in Table 2. IVI of the recorded eight tree species varied considerably across the five forest types. In PW forest type, maximum value for Importance Value Index (IVI) was recorded for *Pinus wallichiana* (188.33) followed by *Abies pindrow* (44.96), *Picea smithiana* (32.01) and a minimum of (17.35) for *Cedrus deodara* and *Aesculus indica*. Similarly, *Abies pindrow* (171.90), *Cedrus deodara* (209.67), *Picea smithiana* (184.26) and *Betula utilis* (266.50) were the abundant species in AP, CD, PS, and BU forest types respectively in terms of IVI.

Table 1 Summary of Stand parameters and tree diversity in different forest types of Kashmir Himalaya.

Forest Type	Evenness	Shannon-Wiener Index	Simpsons Index	Density (Trees/ha)	Basal Area (m^2/ha)
PW	0.40	0.65	0.70	581.81±205.1	55.89±53.26
AP	0.46	0.81	0.63	554.54±176.5	59.81±36.80
CD	0.35	0.48	0.78	416.66±175.1	63.03±30.02
PS	0.39	0.71	0.67	475.00±166.6	49.42±22.14
BU	0.19	0.13	0.94	866.67±577.7	33.36±25.09

PW = *Pinus wallichiana*, AP = *Abies pindrow*, CD = *Cedrus deodara*, PS = *Picea smithiana* and BU = *Betula utilis.*

Table 2 Importance value index (IVI) species wise in five forest types of Kashmir Himalaya.

Name of species	Forest Types				
	PW	AP	CD	PS	BU
Pinus wallichiana	188.33	34.35	37.67	36.87	-
Abies pindrow	44.96	171.90	22.56	42.37	33.50
Cedrus deodara	17.35	-	209.67	-	-
Picea simithiana	32.01	38.59	30.11	184.26	-
Betula Utilus	-	-	-	-	266.50
Acer caesium	-	16.39	-	18.25	-
Aesculus indica	17.35	22.38	-	18.25	-
Taxus sp.	-	16.39	-	-	-

3.2 Biomass

Biomass Levels in different forest types of Gulmarg forest range are given in Table 3 indicates that there is a considerable variation in biomass of different forest types. A great difference has been observed in aboveground biomass (AGB) and belowground biomass (BGB) which led to an overall difference in the total biomass (TB) in the forest types under study. Field estimated biomass data of different forest types reveal that maximum total biomass is found in CD forest type (496.7±278.9 Mg ha^{-1}) and minimum total biomass is found in BU forest (319.2±208.5 Mg ha^{-1}) (Table 3). Mean AGB of trees in five different forest types ranges from 253.3±165.9 Mg ha^{-1} to 393.7±221.3 Mg ha^{-1} while the mean BGB ranges from 65.9±43.01 Mg ha^{-1} to 102.9±57.6 Mg ha^{-1}. Total growing stock volume was highest for CD forest type (665.3±371.7 m^3 ha^{-1}) and lowest for BU forest (383.4±250.4 m^3 ha^{-1}).

Table 3 Biomass Levels in different forest types of Gulmarg forest range.

Forest Type	Tree Volume (m^3 ha^{-1})	AGB (Mg ha^{-1})	BGB (Mg ha^{-1})	TB (Mg ha^{-1})
PW	609.3±522.5	328.6±281.1	85.4±73.0	414.0±354.1
AP	587.5±443.9	358.4±276.5	93.21±71.88	451.7±348.3
CD	665.3±371.7	393.7±221.3	102.9±57.6	496.7±278.9
PS	508.6±407.7	306.4±239.5	81.1±60.9	387.6±300.3

BU	383.4±250.4	253.3±165.9	65.9±43.01	319.2±208.5
Mean Total	476.2±181.5	282±99.67	73.74±26.16	355.8±125.9

Where, AGB = Aboveground biomass, BGB = Belowground biomass and TB = Total biomass.

3.3 Species wise biomass contribution

In BU forest type, dominant species was BU which contributed to 96.86% of the aboveground and belowground biomass than other species of tree (Table 4), whereas PW, CD, PS and AP contributed 91.19%, 87.96%, 83.04% and 78.18% respectively (Fig. 2), of the total aboveground and belowground biomass.

Table 4 Tree biomass (Mgha^{-1}) species wise in study area.

Name of species	Forest Types				
	PW	AP	CD	PS	BU
Pinus wallichiana	377.52±50.54	64.44±15.54	27.88±5.00	23.18±10.59	-
Abies pindrow	31.24±34.17	353.12±81.49	21.02±0.00	36.02±11.99	10.02±1.41
Cedrus deodara	1.57±0.00	-	436.89±114.98	-	-
Picea simithiana	2.81±2.53	23.25±4.15	10.88±5.86	321.81±10.14	-
Betula Utilus	-	-	-	-	309.16±23.02
Acer caesium	-	3.62±0.00	-	3.32±0.00	-
Aesculus indica	0.85±0.00	5.46±3.05	-	3.16±0.00	-
Taxus sp.	-	1.74±0.00	-	-	-

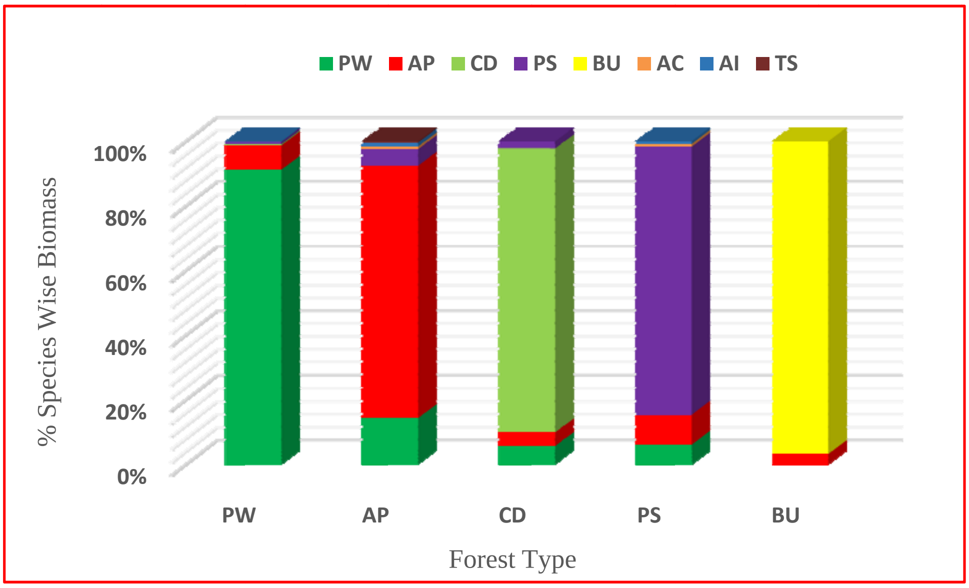

Fig. 2 Species wise percentage contribution of total tree biomass in five forest types study area,Where BU = *Betula utilis*, CD = *Cedrus deodara*, AP = *Abies pindrow*, PS = *Picea smithiana*, AC = *Aesculus indica*, AC =*Acer caesium*, TS = *Taxus sp.*and PW = *Pinus wallichiana.*

3.4 Carbon stock

Aboveground carbon (AGC) stocks of trees varied among different forest types (Table 5). Data reveals that maximum total aboveground carbon is obtained in CD forest type (181.12±7.27 Mg ha^{-1}) whereas, minimum total AGC is found in BU forest type (113.99±8.73 Mg ha^{-1}). Belowground carbon (BGC) stock follows the similar trend as observed in that of aboveground carbon that is carbon in CD forest type (181.12±7.27 Mg ha^{-1}) > AP (42.71±2.76 Mg ha^{-1}) > PW (39.29±12.83 Mg ha^{-1}) > PS (37.33±3.01 Mg ha^{-1}) > BU forest (29.63±2.72 Mg ha^{-1}). Box plot (Fig. 3) showing the parameters of range, median, first quartile and third quartile was obtained for forest type wise biomass carbon values.

Table 5 Forest carbon pools in different forest types of Kashmir Himalaya.

Components	Carbon (Mg C ha^{-1})					Mean
	PW	AP	CD	PS	BU	
AGC	151.15±49.36	164.24±10.64	181.12±7.27	140.94±11.58	113.99±8.73	156.23±16.57
BGC	39.29±12.83	42.71±2.76	47.34±1.90	37.33±3.01	29.63±2.72	39.26±6.58
(AGC+BGC)	190.45±162.9	207.76±160.24	228.47±128.3	178.55±138.19	143.63±93.87	189.8±31.89

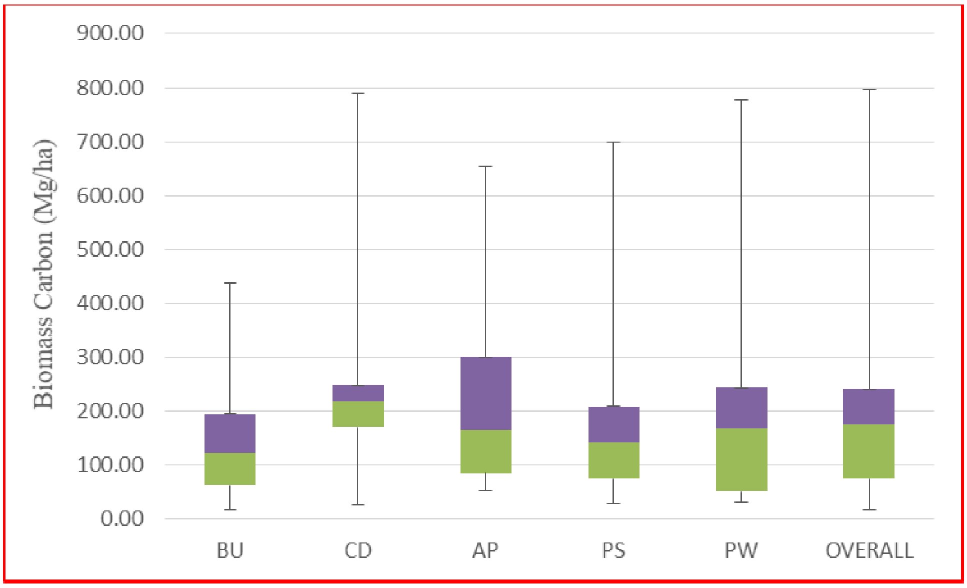

Fig. 3 Box plot for biomass carbon values for different forest type and overall sampled area.

4 Discussion

Variations in species distribution, basal area and density (Table 1) in temperate forest ecosystems occur due to changes in altitude, topography and climatic conditions, as well as forest types, diameter class and lack of uniform plot dimensions (Shaheen et al., 2012; Sundarapandian and Pascal, 2013; Dar and Sundarapandian, 2016; Singh et al., 2016). The higher Shannon diversity index values in AP forest type are due to presence of different tree species. Higher value of Simpson's index value (0.94) recorded for BU forest type is due to monospecific nature and dominance of a single tree species. The Shannon diversity index value derived from the present study is comparable to the findings of Dar and Sundarapandian (2016) who reported a Shannon diversity index of 0.18-0.60 for forests of Kashmir Himalaya and lower than the values for other Himalayan regions viz., 1.16 to 3.40 (Sharma et al., 2010; Gairola, 2010; Kunwar and Sharma, 2004; Shaheen et al., 2012). Low tree density in CD forest type is due to presence of mature trees that are large in size as it is protected site. The higher density values in BU forest type is mainly due to the prevalence of trees that are young and smaller in size. Gulmarg forest range showed high tree density range of 416.66-866.67 ha^{-1} as compared to the stem density values of 90 ha^{-1}in western temperate forests of Kashmir Himalaya, Pakistan (Shaheen et al., 2012); 322 ha^{-1} in Kashmir Himalayas (Dar and Sundarapandian, 2015) while it is closer to the values reported in previous studies on moist temperate forests of Himalayas; 820 ha^{-1}(Dhaulkhandi et al., 2008), 380–1390 ha^{-1} (Gairola 2010), 295-850 ha^{-1}(Sharma et al., 2010) and 380-1470 ha^{-1} (Gairola et al., 2011a).

The average basal area of Gulmarg forest range i.e. 58.22 $m^2 ha^{-1}$ (33.36-78.98 m^2 ha^{-1}) is lower than the results reported by Kunwar and Sharma (2004) in trans Himalayan forests of Nepal (90.1-151.9 m^2 ha^{-1}), Ahmed et al. (2006) in Lesser Himalayan moist temperate forests (78–92 m^2 ha^{-1}) and Pande (2001) in Garhwal Himalayas (86–129 m^2 ha^{-1}). However, values are well within the range values recorded by Baduni and Sharma (1996) in temperate forests of Pauri Garhwal, Uttarakhand (19.83-56.46 m^2 ha^{-1}),Gairola et al. (2011a)in moist tropical montane valley slopes of the Garhwal Himalaya, India (32.77-86.56 m^2 ha^{-1}) and Gairola et al. (2012) in Mandal-chopta Garhwal Himalaya, India (32.77-86.56 m^2 ha^{-1}). Low stem density in different forest types in the present study as compared to forests of other regions in Himalayas may be the reason to the lower basal area in this region. Similarly, low basal area in BU forest type could be attributed to occurrence of young and dense population.

Biomass of trees in forest varies with type of forest, species composition, stand area, tree size class, pattern of rainfall, edaphic factors and altitude (Dar and Sundarapandian, 2016). Present study reveals that tree biomass values range from 319.2±208.5 Mg ha^{-1} to 496.7±278.9 Mg ha^{-1} (Table 3), with average value of 355.8±125.9 Mg ha^{-1} which is higher than the range of temperate forests of India as well as those reported by Dar and Sundarapandian (2015) but is well within the range for nearby forests of Kashmir reported by Singh et al. (2012) and Sharma et al. (2011) for forests of Garhwal Himalaya, India. Average biomass in forests of India was 135.6 Mg ha^{-1} and among all states of India, Jammu and Kashmir was having highest value of mean biomass (251.8 Mg ha^{-1}) (Chhabra et al., 2002; Dar and Sundarapandian, 2015). Dar and Sundarapandian (2015) have recorded the biomass range of 243.6±16 Mg ha^{-1} in temperate forest of Kashmir Himalaya. Sharma et al. (2011) also have recorded the biomass range of 633.8±55.3 Mg ha^{-1} in temperate forest of Garhwal Himalaya. In the present study, greater accumulation of biomass is observed as most of the forest types were mature, fully stocked and old age growth forests.

Present study indicates that higher carbon stock is found in CD and AP forest types. This high carbon stocks may be attributed to greatest tree layer biomass. Higher carbon stock of CD, AP and PW forest types compared to that of PS and BU forest indicate that total biomass carbon stock is affected by tree species composition, stand age and management activities (Dar and Sundarapandian, 2015). Present study shows that BU biomass carbon (Table 1) are greater than those reported by Singh et al. (1994) and Dar and Sundarapandian (2015). Globally similar results (99.1-182.7 Mg ha^{-1}) have been observed (Zhu et al., 2010). AGC range values (46-320 Mg ha^{-1}) in Kumaun, Central Himalaya by Singh et al. (1994) shows harmony with AGC results of present study (Table 2). Present study reveals tree biomass carbon value ranged between 143.63±93.87 and 228.47±128.3 Mg C ha^{-1}, with mean total value of 189.8±31.89 Mg C ha^{-1}.Tree biomass carbon values revealed in the present study are in harmony with the values reported by Bhat et al. (2013), Rana et al. (1989), Sharma et al. (2011) and Gairola et al. (2011b). However, biomass carbon measured during present study are greater than those reported by Dar and Sundarapandian (2015), Wani et al. (2015) and Brown et al. (1999).

Correlation and regression analyses showed that basal area has a positive correlation-with total biomass (Fig. 4). This positive correlation that exists between the basal area and total biomass in the current study is similar to results obtained by Brown et al. (1989), Chaturvedi et al. (2011) and Dar and Sundarapandian (2015).

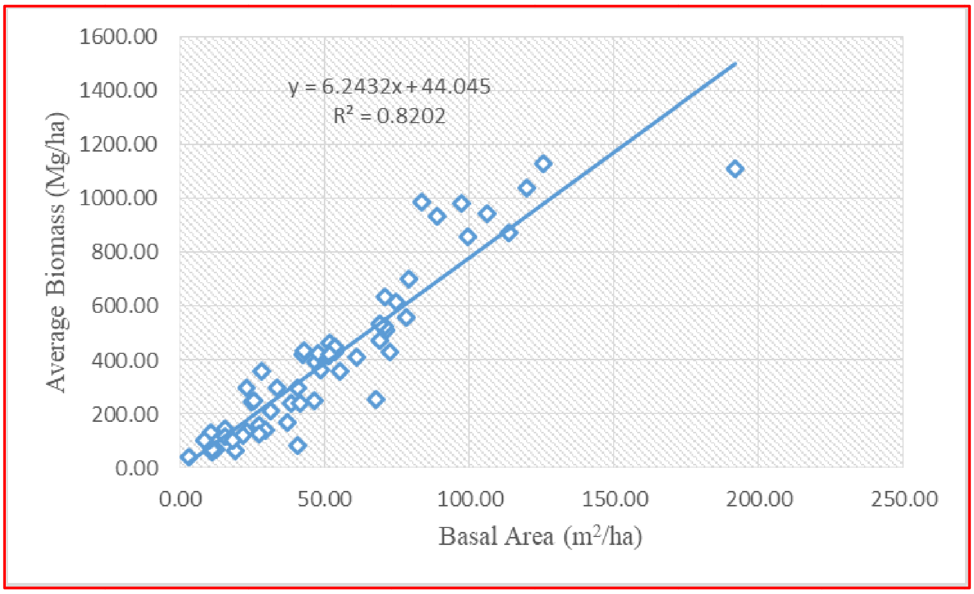

Fig. 4 Relationship between basal area with biomass in five forest types of Gulmarg forest range.

Present study indicates higher values of both tree biomass and tree carbon stocks as compared to other parts of the same region. This may be attributed to occurrence of moisture and favourable environment of this northern region. The environmental variation in northern and southern sides of Kashmir Himalaya is due to availability of unequal solar radiation. Southern slopes of Himalaya receive less sunlight, so they are relatively cool as compared to northern side of Himalaya which receives higher insolation. This forms better growing conditions on the northern side compared to that of the southern side.

5 Conclusion

Carbon stock is distinctly variable in all the five forest types available at Northern Kashmir Himalaya. Carbon stocks of different forest types are different from each other due to vegetation variation, age of stand and forest type environment. Present study revealed CD forest type with comparatively mature girth classes in more number shows highest biomass carbon 228.47±128.3 Mg C ha^{-1}. Hence, CD can enhance global carbon mitigation more effectively in the study area with the same given set of climatic and soil conditions. Therefore, it can be concluded that temperate forest of northern Kashmir Himalaya sustain higher carbon stock and it should be conserved properly as it plays a key role in reduction of carbon emission. It can be suggested from the present study that increases in the coverage of protected area and afforestation using CD species in Gulmarg forest range will be very much effective for carbon sequestration and hence may reduce the adverse impact of microclimatic change. The same management option can be replicated in forests having the same climatic and altitudinal conditions.

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