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ASSESSMENT OF BIOMASS AND CARBON STOCKS IN CONIFEROUS FOREST OF DIR KOHISTAN, KPK

Adnan Ahmad[1,*], Sarwat N. Mirza[2] and S.M. Nizami[2]

[1]Department of Forestry, Shaheed Benazir Bhutto University Sheringal, Dir Upper KPK , Pakistan
[2]Faculty of Forestry, Range Management & Wildlife, PMAS-Arid Agriculture University Rawalpindi, Pakistan
[*]Corresponding author's e-mail: adnanforester777@yahoo.com

The present study estimates total biomass and carbon stocks of the coniferous forest of Dir Kohistan. The biomass and carbon stocks were assessed by using inventory data. The results indicated that stem density ranged from 224 trees ha^{-1} in mix coniferous forest to 166 tree ha^{-1} in mixed *Abies pindrow* and *Picea smithiana* forest. Stem volume ranged from 369.49 m^3 ha^{-1} in mixed *Cedrus deodara* and *Pinus wallichiana* forest to 440.70 m^3 ha^{-1} in mixed coniferous forest. The overall recorded mean stem density was 191 trees ha^{-1} constituting 400.89 m^3 ha^{-1} stem volume. The estimated average biomass was 258.98 Mg ha^{-1}. The mean carbon stock was 129.49 Mg ha^{-1} .The total calculated biomass from coniferous forest was 16.12 Tg. The total carbon stored by forest was 8.06 Tg. Through afforestation of blank area (5523.7 ha) the study area can sequester 0.7141 Tg carbon in future.
Keywords: Hindu Kush, growing stock, biomass, carbon stocks, coniferous forest

INTRODUCTION

The concentration of CO_2 in the atmosphere is expanding due to various human activities. Forests acts as a sink of carbon. Clearing of forest not only cause an addition of CO_2, but also destroy valuable sink of carbon. The major issue of worldwide imperativeness today is the increase level of CO_2 from 315 ppm in 1959 to 399.89 ppm in 2013 (NOAA, 2013). Plant biomass constitutes a significant carbon stock in many ecosystems. Biomass is present in both aboveground and belowground parts of annual and perennial plants. Biomass associated with annual and perennial herbaceous plants is relatively ephemeral, i.e., It decays and regenerates annually or every few years. Woody plants and trees can accumulate large amounts of carbon (up to hundreds of tons ha^{-1}) over their lifespan (IPPC, 2006). Forests are the natural storage factory of carbon and the assessment of carbon present in the biomass of forest is the important component to determine the contribution of forestland to global carbon cycle (Gairola *et al*., 2011).

Among terrestrial ecosystem forest has the largest potential to alleviate global climate change due to its woody character (Sharma *et al*., 2011; Danquah *et al*., 2012). Forest has the potential to store 20 to 50 times more carbon than barren lands (Houghton and Hackler, 1995). Increasing forest area is the effective means to reduce global warming and mitigate elevated level of atmospheric carbon dioxide (Sharma *et al*., 2011; Tolnnay, 2009; Bala *et al*., 2007).

Around the globe, countries try to fulfill their commitments under the United Nations Framework Convention on Climate Change (UNFCCC), and Kyoto Protocol. Under Kyoto Protocol the improved countries of the globe go to consent to chop down emission of green house gases 5% underneath 1990 level throughout commitment period of 2008-2012. Article 3 of Kyoto Protocol gives bearings and directing standards to chop down their greenhouse gas emanation and acquire a net change in GHGs outflow by sources and evacuation by the sinks. The Kyoto Protocol additionally push onto measure net discharge of GHGs and carbon sequestration that what amount of progress happen in carbon stocks, and additionally calls to advance a gauge for carbon stocks.

Pakistan is signatory to Kyoto Protocol. Being a signatory to the protocol the budgeting of carbon in the forests of Pakistan are in initial stages. The present study was conducted in the Hindukush region of Pakistan. The present study was aimed to gauge biomass and carbon stocks in the coniferous forest of Dir Kohistan using inventory data. This region comprises of huge tracts of coniferous forest manage under the selection silvicultural system and has great potential to sink atmospheric carbon dioxide. The present study provides details information about biomass, carbon stock and future carbon sequestration potential of the area. The objectives of the study were to estimate biomass of the coniferous forest of the study area and to calculate carbon stocks of the coniferous forest of the study area.

MATERIALS AND METHODS

Study area: Dir Kohistan is located to the North West side of Khyber Pukhtunkhwa province Pakistan. It is located between latitude 35°-9\` to 35°-47\` and longitude 71°-52\` to 72°-22\`. The total area of Dir Kohistan is 167032 ha. The elevation ranges from 1000 m to 5500 m. The mean annual

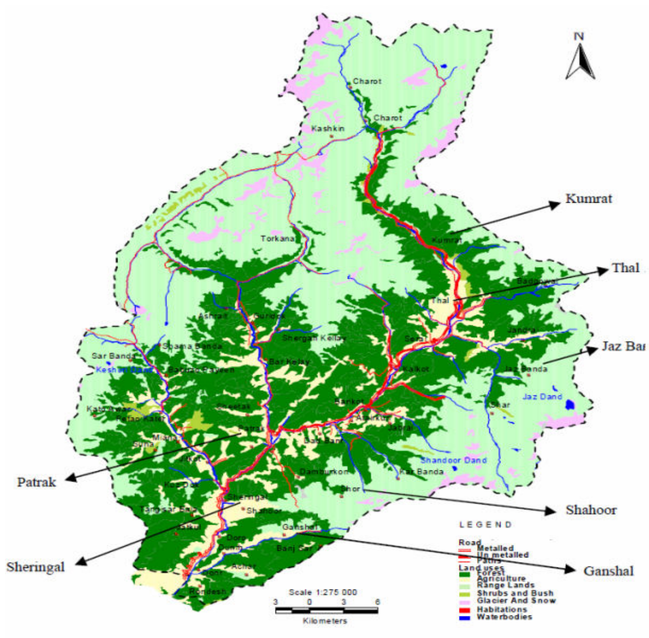

Figure 1. GIS Map of study area (Arrows indicates major villages of study area)

precipitation in area ranges from 1000 to 1600 mm. Temperature ranges from 0.7 to 32°C. Diorites, norities, schist are the principles types of rocks. The soil is loam or sandy loam rich in organic matter. A GIS map of study area is given in Figure 1 which indicated different land uses. The total forest area of Dir Kohistan is about 153236.24. Of the total forest area of Dir Kohistan the coniferous forest covered 56822.27 ha area that started at elevation of 1700 m to 3182 m. The coniferous forest of study area were classified into pure *Cedrus deodara* (Deodar) forest (0.71%), mixed *Cedrus deodara* and *Pinus wallichiana* (Kail) forest (1.59%), mix *Abies pindrow* (Fir) and *Picea smithiana* (Spruce) forest (1.49%) and mix coniferous forest (96.01%). Mix coniferous forest comprised of *Cedrus deodara*, *Pinus wallichiana*, *Abies pindrow* and *Picea smithiana*.

***Growing stocks assessment and data source*:** For present study data of Growing stock and stem density was taken from the inventory carried out by the respective forest department of Dir Kohistan (Saddozai, 1995). The data were collected from 293 compartments covering an area of 29500 ha. For these purposes point sampling techniques was used. A prism of Basal area factor (BAF) 20 was used. During inventory 14 to 29 points in each compartment (293) were taken and at each point all the "In" trees were recorded. Height and increment of trees from diameter 15.24 cm and above were recorded. The volume of each sample tree to respective diameter was calculated. The inventory data were summarized in the stand and stock table. In stand - stock table volume per tree, total number of trees and total volume to a respective diameter class (from 15 cm to 147 cm by diameter interval 2.54 cm) was given. Compartments wise stem density and growing stock data for 293 compartment covering an area of 29500 ha was also available. For the calculation of stem density and volume in each forest stand separate compartment wise data was used. In each compartment trees were classified into four diameter classes of 15-38 cm, 39-58 cm, 59-78 cm, and 79 cm and above. While in the stand and stock table total number of trees and their respective growing stocks were given to each diameter class from15 cm to 147 cm (diameter interval 2.54 cm).

***Biomass calculation*:** Stem biomass was calculated from the volume (m^3) and wood density of respective tree species. Wood densities for all tree species were sourced from available literature (Haripriya, 2000). Following formula was used to calculate stem biomass

$$\text{Stem biomass} = \text{Volume } (m^3) \times \text{Basic wood density } (kg/m^3)$$

For the calculation of total biomass, Biomass expansion factors (BEF) of each component were used. The BEF ratio of 1.51 was used for the estimation of total tree biomass. This ratio had been used by (Haripriya, 2000) for coniferous species to estimate total tree biomass in the Indian forest. Total biomass was determined using the following relation.

$$\text{Total biomass} = \text{Stem biomass} \times \text{BEF}$$

***Carbon stocks calculation*:** Total carbon stocks (Mg ha^{-1}) were calculated from total biomass. For the conversion of biomass to carbon stocks conversion factor of 0.5 was used. This conversion factor has been used widely around the Globe (Roy *et al*., 2001; Brown and Lugo, 1982; Malhi *et al*., 2004; Nizami, 2012). Following formula was used to convert biomass to total carbon stocks.

$$\text{Total carbon stocks (Mg } ha^{-1}) = \text{Biomass (Mg } ha^{-1}) \times 0.5$$

RESULTS

***Stem density and volume*:** Stem density ranges from 166 to 224 tree ha^{-1}. The maximum density of 224 trees $ha^{-1}$was recorded in mix conifer forest while the minimum density of 166 trees ha^{-1} was recorded in Mix *Abies pindrow* and *Picea smithiana* forest. Stem density in respective forest stands was arranged in percentages in Table 1. It can be seen from the table that stem density in each forest stands decreases with an increase in diameter. In pure *Cedrus deodara* and mixed conifer forest in total stem density of 177 and 224 trees ha^{-1} 62.94 and 62.05% trees have belonged to 15 to 38cm diameter respectively. While in mixed *Cedrus deodara* and *Pinus wallichiana* forest and mixed *Abies pindrow* and *Picea smithiana* forest 45.66 and 42.85% trees were found in 15 to 38 cm diameter. Number of stems in 79 cm and above (up to 147 cm) diameter classes in each forest stand were minimum and ranges from 4.91% (Mixed conifer forest) to 10.40% (*Cedrus deodara* and *Pinus wallichiana* forest). Using the inventory data volume (m^3) in each forest stand was calculated. Corresponding volume for each diameter class (Table 1) was calculated and their percentage distribution was given in Table 2. It can be seen from Tables 1 and 2 that stem density and volume strongly depend on the diameter of trees. In all forest strata the stem density decreased with an increase in diameter while the stem volume increase with an increase in diameter. In all forest stands the highest volume was recorded in diameter class of 79 cm and above apart of lowest stem density. The presence of large diameter tress resulted more volume in diameter class of 79 to 147 cm.

***Biomass and carbon stocks*:** Stem biomass (Mg ha^{-1}) in all forest stands was measured from the relation of stem volume (m^3 ha^{-1}) and wood density. Details of stem biomass, total biomass and total carbon stocks are summarized in Table 3. Among all forest stand the highest biomass was estimated as 188.86 t ha^{-1}in mixed coniferous forest. Total biomass Mg ha^{-1} was measured using a BEF ratio of 1.51. Total biomass in all forest stands ranged from 223.37 t ha^{-1} in mixed Fir and spruce forest to 284.81 Mg ha^{-1} in mixed coniferous forest. The average biomass of all forest stands was 264.53 Mg ha^{-1}. The mean carbon stocks Mg ha^{-1}in deodar and deodar kail forest was 140.37 and 134.60 Mg ha^{-1} respectively. The average carbon stocks in mixed coniferous forest was calculated as 142.40 Mg ha^{-1}, while in mixed fir spruce forest the average carbon stocks was found 111.68 Mg ha^{-1}.

The average biomass and carbon stock was also calculated from the available stock and stand table of entire region. In stock and stand table to the respective diameter class from 15 cm to 147cm (diameter interval 2.54 cm) stem density, volume per tree and total volume was given. Diameter of trees ranges from 15 cm to 147 cm. The average basal area was 36.01 m^2 ha^{-1}. The mean stem density and volume was

Table 1. Distribution of Stems ha^{-1} (%) in different forest stands by diameter classes[a]

Forest stand	Stem density ha^{-1}	15-38cm	39-58cm	59-78cm	79 and above cm
Pure Deodar	198	56.16	23.94	11.49	8.39
Mixed Deodar and kail	173	45.66	27.16	16.76	10.40
Mixed Fir and spruce	166	42.85	29.22	18.18	9.74
Mixed conifer	224	62.05	21.42	11.60	4.91
Mean	191	53.37	24.78	14.17	7.65

Table 2. Distribution of stem volume ha^{-1} (%) in different forest stand by diameter classes[b]

Forest stand	Volume m^3 ha^{-1}	15-38cm	39-58 cm	59-78 cm	79 and above cm
Pure Deodar	398.98	12.09	22.93	24.37	40.58
Mix Deodar and Kail	369.49	9.769	21.56	28.24	40.42
Mix Fir spruce Forest	392.38	10.38	22.24	30.49	36.86
Mix conifer	440.70	15.43	23.68	29.68	31.19
Mean	400.39				

[a,b] Derived from inventory data(Revised Working plan for Dir Kohistan 1995- 2014)

Table 3. **Stem biomass, total biomass and carbon stocks in t ha^{-1}in each forest stand.**

Forest stand	Volume m^3 ha^{-1}	Wood Density kg m^{-3}	Stem Biomass Mg ha^{-1}	BEF	Total Biomass Mg ha^{-1}	C. Stocks Mg ha^{-1}
Pure Deodar	398.98	466	185.92	1.51	280.74	140.37
Mixed Deodar kail	369.49	482.5	178.28	1.51	269.20	134.60
Mixed Fir spruce	392.38	377	147.92	1.51	223.37	111.68
Mixed conifer	440.70	428	188.62	1.51	284.81	142.40
Mean	400.39		175.18	1.51	264.53	132.26

191 trees ha^{-1} and 400.89 m^3 ha^{-1}. Stem biomass ranged from 54.11 t ha^{-1}(Fir) to 82.6 Mg ha^{-1}(Deodar). The average total biomass was calculated 258.98 t ha^{-1}. The mean carbon stocks in the entire forest area was determined as 129.49 Mg ha^{-1}. Stem density decrease with increase in diameter. To study the relationship of stem density ha^{-1} with diameter (cm) regression model was developed (Fig. 1). Figure 1 shows a strong relation (R^2=0.87) between stem density ha^{-1} and diameter (cm). The relationship between stem density and diameter is quadratic type (Polynomial Inverse 3rd order). Stem volume and stem biomass is the function of basal area. Stem volume m^3 ha^{-1} and stem biomass Mg ha^{-1} increase with increase in basal area (m^2 ha^{-1}). Figure 2 and 3 shows relation between basal area (m^2 ha^{-1}) and stem volume (m^3 ha-1) and stem biomass (t ha-1). The relation is significant with R^2 = 0.962. In both case the relationship was quadratic. Regression models were developed on base of the stand and stock table for the entire region. Stem density, basal area and volume of all trees species (Deodar, Kail, Fir and spruce) were summed and regression models were developed as a whole regardless of species separately.

***Total biomass, carbon stocks and future carbon sequestration potential*:** The total area of the coniferous forest is 56822.27 ha. Inventory data is available for 29500 ha area. From stock and stand table stem density and stem volume ha^{-1} was estimated. Similarly, stem biomass, total biomass and carbon stock were measured on per hectare basis and was extrapolated to the entire region 56822.27 ha. The results are presented in Table 5.The results of the table showed total carbon stocks of entire region of the different forest stand. The coniferous forest of the region stored about 8.06 Tg C (129.29Mg ha^{-1}). In the present study the total blank area was estimated from the records of each compartment. It was found that in the entire region about 5523.07 ha of forest area were blank. If the blank area is properly managed and bring under forest, the ability of an area can be increased in term of carbon sequestration. If we consider the current amount of 129.29 t ha^{-1} of carbon stock, and the blank area of the region is afforested, it may sequester 0.7141 Tg C in the future.

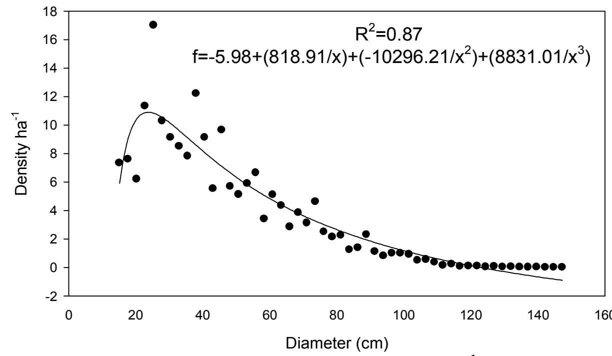

Figure 2. Relation b/w stem density ha^{-1} and diameter (cm)

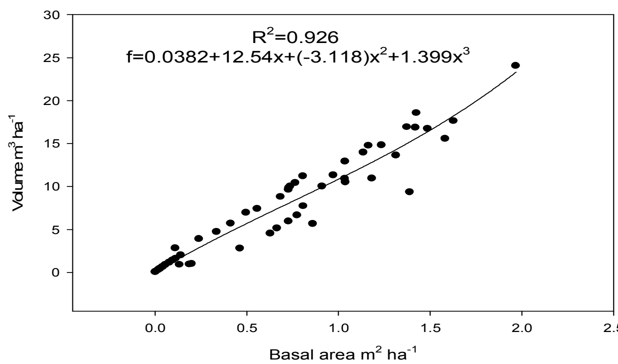

Figure 3. Relation b/w stem volume m^3 ha^{-1} and basal area m^2 ha^{-1}

Table 4. Stem density (ha^{-1})[a] basal area (m^2 ha^{-1})[b], volume (m^3 ha^{-1})[c], stem biomass (Mg ha^{-1}), total biomass (ha^{-1}) and carbon stocks (ha^{-1}) based on stock and stand table of the area.

Specie	Density ha^{-1}	B. Area m^2 ha^{-1}	Volume m^3 ha^{-1}	W. Density Kg m^3	S. biomass Mg ha^{-1}	BEF	T. biomass Mg ha^{-1}	C. Stocks Mg ha^{-1}
Deodar	62	11.12	117.43	466	54.72	1.51	82.62	41.31
Kail	36	6.72	81.17	499	40.50	1.51	61.15	30.57
Fir	45	8.57	96.35	372	35.84	1.51	54.11	27.05
Spruce	48	9.63	105.94	382	40.47	1.51	61.10	30.55
Total	191	36.04	400.89		171.53	1.51	258.98	129.49

Source: [a,b,c] Derived from inventory data (Revised Working plan for Dir Kohistan 1995- 2014)

Table 5. Total biomass and carbon stocks in Tg of the entire region.

Forest stand	Total area (ha)[a]	Blank area (ha)[b]	Total biomass Tg	Total carbon stocks Tg
Pure Deodar	485.00	38.00	0.137	0.06
Mix conifer	54584.11	5272.42	15.550	7.77
Mix Deodar kail	903.60	141.00	0.244	0.12
Mix Fir spruce	849.56	71.65	0.189	0.09
Total	56822.27	5523.07	16.120	8.06

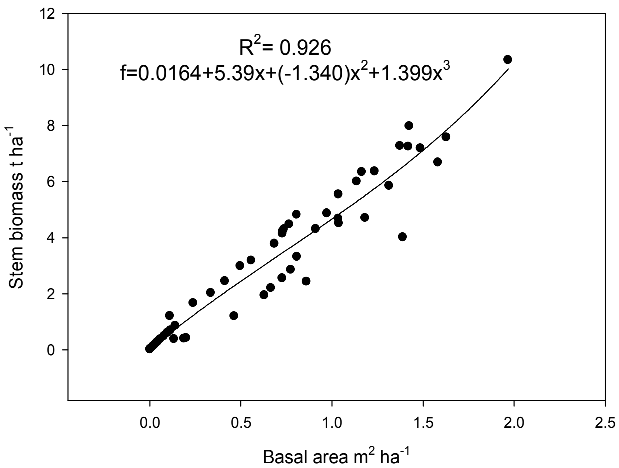

Figure 4. Relation b/w stem biomass t ha^{-1} and basal area m^2 ha^{-1}

DISCUSSION

In present study stem density of 224 tree ha^{-1} in mix conifer forest, 197 tree ha^{-1} in pure deodar forest and 173 tree ha^{-1} in deodar kail forest falls with the expected range of 240 (mixed conifer forest), 184±20 (deodar) and 185 (deodar-kail) tree ha^{-1} reported by Moinuddin *et al.* (2010) from different region of Pakistan. Stem density of 166 trees ha^{-1} in fir spruce forest was lower than the estimated value of 215 trees ha^{-1} by Haripriya (2000). The reason of low density was the exclusion of less than 15cm diameter trees from the inventory. Stem density decreases with increase in tree diameter (Nizami, 2012). In the present study, out of total trees ha^{-1} about 53% trees were found in diameter class of 15 to 38 cm and about 7% trees were found in diameter classes of 79 cm and above.

Growing stock based estimation of biomass and carbon stocks are the reliable and valuable source (Haripriya, 2000; Tolunaly, 2009; Chhabara *et al*., 2002; Walle *et al*., 2005). In the present study, inventory data already collected by the respective forest department was used to determine biomass and carbon stocks based on growing stocks estimations. The present stem volume of 392.38m^3 ha^{-1} in fir-spruce forest is comparable to the estimated volume of 383.1m^3 ha^{-1} by Haripriya (2000) but the volume in case of the deodar forest (398.98m^3 ha^{-1}), and mixed conifer forest (440.71 m^3 ha^{-1}) shows high value. It is due to the presence of larger diameter trees (8.39 and 4.91 percent) in diameter class of 79 cm as against 2.1 and 1.4 percent in diameter class 70cm and above. The value of mean biomass 258.98 t ha^{-1} of the region is within the range of 121.33-247.21 t ha^{-1} reported by Tiwari *et al.* (2005). Total carbon of the entire region ranged between 111.68 (fir and spruce forest) to 142.40 (mixed coniferous forest) t ha^{-1} with a mean value of 129.29 t ha^{-1}. The present values of carbon stocks of the region are consistent with studies of Sharma *et al*. (2007).

Forest biomass have great potential to store carbon (Houghton, 2005). Afforestation can be a potential step to control global warming (Sharma *et al*., 2011; Tolnnay, 2009; Bala *et al.*, 2007; Misir *et al*., 2013). Watson (2000) proposed that increasing forest area through plantation is the most effective way to mitigate global warming and cut down an elevated CO_2. The present estimate of biomass and carbon stocks was based on already collected inventory data of the region. By afforestation and plantation of the blank areas, and increasing forest cover through various forest management activities, the potential of the region can be increased to sequester and store carbon. Smaller trees had less volume, as compared to larger trees, but their proportion in number of trees is more and can be an important part of total biomass (Haripriya, 2000). In the present study, trees of less than 15 cm diameter were not taken, as inventory data was available for greater than 15 cm diameter trees only. The omission of trees less than 15cm diameter resulted in relatively less biomass and carbon stocks. Carbon stocks present in trees less than 15cm diameter, understory vegetation, dead wood, litters and soil was not calculated. If the carbon stocks of the all respective components (Trees, understory vegetation, dead wood, litters and soil) were calculated, the present carbon stock would have been in the range of 180 – 230 t ha^{-1}.

***Conclusions*:** The Karakorum region of Pakistan has great potential to store and sink atmospheric carbon. In the present study, it was found that the coniferous forest of the region stored about 129.29 t ha^{-1} carbon (excluding soil carbon). Right management of woodland and increasing forest cover in the region, afforestation of blank and waste land and plantation establishment can be regarded as important steps to increase the potential of the region in term of carbon sequestration. By taking suitable measures and promoting research, the study area can be included in carbon trading under CDM Article 12 of Kyoto protocol and REDD++ in the future.

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REFERENCES

Brown, S. and A.E. Lugo. 1982. The storage and production of organic matter in tropical forest and their role in Global carbon cycle. Biotropicia 14: 161-187.

Bala, G., K. Calderia, M. Wickett, T.J. Phillips, B.D. Lobel, C. Delire and A. Mirin. 2007. Combine climate and carbon cycle effects of large scale deforestation. Proc. Nat. Acid. Sci. USA 104: 6550-6555.

Chhabara, A., S. Palriab and V.K. Dadhwala. 2002. Growing stock-based forest biomass estimate for India. Biomass and Bioenergy 22: 187-194.

Danquah, J.A., M. Appiah and A. Pappinen. 2012. The effect of African mahogany species on soil chemical properties in degraded dry semi-deciduous forest ecosystems in Ghana. Int. J. Agric. Biol. 14: 321–328.

Gairola, S., C.M. Sharma, S.K. Ghildiyal and S. Sarvesh. 2011. Live tree biomass and carbon variation along altitudinal gradient in moist temperate valley slopes of Garhwal Himalaya India. Curr. Sci. 100: 1862-1870.

Haripriya, G.S. 2000. Estimates of biomass in Indian forests. Biomass and Bioenergy 19: 245-258.

Houghton, R.A. and J.L. Hackler. 1995. Continental scale estimate of the biotic carbon flux from land cover change 1850- 1990. ORNL/CDIAC-79, NDP-050, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, USA.

Houghton, R.A. 1997. The annual net flux of carbon to atmosphere from change in land use 1850- 1980. Telllus 51b: 298-213.

Houghton, R.A. 2005. Aboveground forest biomass and the global carbon balance. Glob. Change Biol. 11(6): 945-958.

IPCC. 2006. Guidelines for National Greenhouse Gas Inventories. Available online with updates at www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Kyoto. 1997. Kyoto Protocol to UN Framework Convention on Climate Change. UN, New York, USA.

Malhi, Y., T.R. Baker, O.L. Phillips, S. Almeida, E. Alvarez, L. Arroyo, J. Chave, C.I. CzimczikI, A.D. Fiore, N. Higuchi, T.J. Killeen, S.G. Laurance, W.F. Laurance, S.L. Lewis, L.M.M. Montoya and J. Lloyd. 2004. The above ground coarse wood productivity of 104 Neotropical forest plots. Glob. Change Biol. 10: 563-591.

Misir, M., N. Misir, S. Bayburtlu and F. Bilgili. 2013. The yield of natural trembling aspen (*Populus tremula* L.) stands (Northern and Eastern Anatolia). Pak. J. Agri. Sci. 50: 537-547.

Moinuddin, A., S.S. Shaukat and M.P. Siddiqui. 2011. A multivariate analysis of the vegetation of *Cedrus deodara* forests in Hindu Kush and Himalayan ranges of Pakistan: evaluating the structure and dynamics. Turk. J. Bot. 35: 419-438.

Nizami, S.M. 2012. The inventory of the carbon stocks in sub tropical forest of Pakistan for reporting under Kyoto Protocol. J. For. Res. 23(2): 377-384.

NOAA. 2012. Atmospheric CO_2 Mauna Loa Observatory (Scripps/ NOAA). Available online with updates at http://co2now.org

Roy, J., B. Saugier and H.A. Mooney. 2001. Terrestrial global productivity. Academic, San Diego.

Sharma, P. and S.C. Rai. 2007. Carbon sequestration with land-use cover change in a Himalayan watershed. Geoderma 139: 371-378.

Saddozai, A.Q.K. 1995. Revised Working Plan for Dir Kohistan Forest, 1995- 2014. KPK Forest Department, Peshawar, Pakistan.

Sharma, C.M., S. Gairola, N.P. Baduni, S.K. Ghildiyal and S. Sarvesh. 2011. Variation in carbon stocks on different slope aspects in seven major types of temperate region of Garhwal Himalaya, India. J. Biosci. 36(4): 701-708.

Tolnnay, D. 2011. Total carbon stocks and carbon accumulation in living tree biomass in forest ecosystem of Turkey. Turk. J. Agric. For. 35: 256-279.

Tiwari, A.K., A. Agarwal, K. Sunil and S.C. Tiwari. 2005. Analysis of land use and biomass in Khanda watershed, Garhwal Himalaya, using satellite remote sensing data. Tropical Ecology 46(2): 253-263.

UNFCCC. 2001. Kyoto Protocol. Available online with updates at http//www.unfccc.de/resource/protintr.html.

Walkley, A. and J.B. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic titration method. Soil Sci. 37: 29-38.

Walle, I.V., N.V. Camp, D. Perrin, R. Lemeur, K. Verheyen, B.V. Wesemae and E. Laitat. 2005. Growing stock-based assessment of the carbon stock in the Belgian forest biomass. For. Sci. 62: 1-12.

Watson, R.T. 2000. Land use, land-use change, and forestry: A special report of the IPCC, Cambridge: Cambridge University Press; pp.377.