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ANNUAL ACCUMULATION OF CARBON IN THE CONIFEROUS FOREST OF DIR KOHISTAN: AN INVENTORYBASED ESTIMATE

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Abstract

The present study figured out net annual accumulation of carbon in coniferous forest of Dir Kohistan. In present study the annual diameter growth (cm), mean annual increment (m^3 $ha^{-1}yr^{-1}$) total gain and loss in biomass in biomass (t $ha^{-1}yr^{-1}$) and total gain and loss of carbon (t $ha^{-1}yr^{-1}$) was assessed. The results of the study showed that *Pinus wallichiana* has mean maximum annual diameter growth of 0.28±12cm yr^{-1} while minimum growth was recorded in *Abies pindrow* (0.23±0.056 cm). The mean annual increment of the forest was 5.07m^3 $ha^{-1}yr^{-1}$, while total estimated biomass gained by the forest was 3.31t $ha^{-1}yr^{-1}$. The mean input of biomass C stock was 1.65 t $ha^{-1}yr^{-1}$. The study revealed that total biomass removal from the forest in the form of fuel wood, timber consumption and illegal cutting was 2.97t $ha^{-1}yr^{-1}$ that accounts for 1.48 t $ha^{-1}yr^{-1}$ of carbon losses. The results of the study concluded that the coniferous forest of Dir Kohistan can sequester mean carbon of 0.17 t $ha^{-1}yr^{-1}$ from atmosphere. The results of the present study confirmed that the forest of the study area acts as a net sink of carbon.

Key Words: Dir Kohistan, Coniferous forest, Carbon Accumulation

Introduction

The alarming issue around the globe is the increased level of Carbon dioxide in atmosphere. The current concentration of Carbon dioxide) in atmosphere is 399 ppm (Adnan *et al*., 2014). This increase in level of CO_2 is responsible for the warming of earth and global climate change. Among terrestrial ecosystem, forest ecosystem has great potential to mitigate global climate change due to its woody nature (Sharma *et al*., 2011; Ahmad *et al*., 2014). Woody plants and trees can sequester and store huge amount of carbon through their life cycle (Anon., 2006). Forest store significant amount of carbon in their biomass, to find out the contribution of forest land in global carbon cycle it is necessary to estimate the stock carbon in the biomass of trees (Gairola *et al*., 2011). Forest land stores 20 to 100 times more carbon as compared to barren land (Houghton & Hackler, 1995). In order to control the elevated CO_2 level in atmosphere it is required to increase forest area (Sharma *et al*., 2007; Tolnnay, 2009; Bala *et al*., 2007).

To address the problem of global warming and climate change, the United Nation's conference of parties adopted Kyoto protocol in 1997. The protocol declares forest as a potential sink of carbon. Article 3 of the protocol gives direction and guideline to reduce greenhouse gases emission. The protocol also stresses on the member countries to conduct regular inventories for greenhouse gases emission from different sources and removal by sinks. The Kyoto Protocol also developed different mechanism like Joint implementation, emission trading and clean development mechanism (CDM). Among the three mechanisms CDM is the potential tools for developing countries to attract investment and environmental friendly technologies from developed countries for their sustainable development (Gairola, *et al*., 2011; Anon., 2005). The mechanism also stresses on developing countries to promote clean energy, energy efficiency, renewable energy and forestry related activities. The CDM also established different projects like CDM afforestation and reforestation project that would cut down carbon emission for that the developing country will received payment.

Pakistan is signatory to the Kyoto protocol and United Nations framework on climate change. To estimate carbon stored in the forest of Pakistan some studies have been conducted for the estimation of carbon stock in different forest types of Pakistan (Nizami, 2012; Adnan & Nizami, 2014; Adnan *et al*., 2014). In order to estimate annul carbon sequestration potential of the forest of Pakistan there is a lack of information. Up till now, no sophisticated study has been carried out on annual carbon accumulation of carbon in the forest of Pakistan. In order to bridge the gap, the present study was conducted in the coniferous forest of Dir Kohistan, Khyber Pakhtunkhwa, Pakistan. The present study not only provides information about annual carbon accumulation in the coniferous forest of Dir Kohistan but also gives information about total carbon losses from the forest upon removal of biomass in the form of timber, fuel wood, and illegal cutting. This study will provide a base line for further research for the monitoring and assessment of annual accumulation of carbon in living biomass of the coniferous forest of Pakistan. The objective of the study were (1) to assessed the amount of carbon stored in the biomass of forest each year (2) to estimate the amount of carbon removed from forest each year and to find out net annual accumulation of carbon each year in the coniferous forest.

Materials and Methods

Study area: The present study was carried out in Dir Kohistan, Khyber Pakhtunkhwa, Pakistan. The total area of Dir Kohistan is 167032.39 ha. Geographically the study area is located at 35°9` to 35°47`latitude and 71°52' to 72°22'longitude. The elevation of the study site ranges from1676.82 to 5750m. The mean annual precipitation ranges from 1000 mm to 1600 mm, while the mean annual temperature ranges from 0 to 32°C. The coniferous forest of the study region starts from 1676m up to a height of 3200m that covers an area of 56822.27 ha. The coniferous forest of study area were classified into pure *Cedrus deodara* (Deodar) forest, mixed *Cedrus deodara* and *Pinus wallichiana* (Kail) forest, mix *Abies pindrow* (Fir) and *Picea smithiana* (Spruce) forest and mix coniferous forest. Mix coniferous forest comprised of *Cedrus deodara*, *Pinus wallichiana*, *Abies pindrow* and *Picea smithiana.*

Mean annual growth (cm), Mean annual increment (m^3 ha^{-1}) and total wood (m^3 ha^{-1}) estimation: The annual growth data was collected from the forest inventory data of Dir Kohistan forest division. Inventory data is given in the forest working plan (1995-96 to 2014 to 2015) of Dir Kohistan. For the estimation of annual diameter increment overall, a total of 5347 trees were sampled in all diameter class from 15 cm to 152 cm with diameter interval of 2.54 cm. Growth record for the last ten years was taken using increment borer and mean annual diameter increment was calculated in each forest stand. From the present and future Stock table prepared for each forest stand total annual volume increment (m^3 ha^{-1}) was determined. The mean annual increment (m^3 ha^{-1} yr^{-1}), total volume increment (m^3 ha^{-1} yr^{-1}) and amount of wood that is extracted per year illegally has been presented in Table 1.

Biomass calculation: Stem biomass (t ha^{-1}) for the respective trees species was calculated from the total annual volume increment (m^3 ha^{-1}) and basic wood density (kgm^{-3}). Annual volume increment (m^3 ha^{-1}) was assessed from already inventory data while wood density (kgm^{-3}) for each tree species was sourced from available literature (Haripriya, 2000; Ahmad *et al*., 2014). Stem biomass (t ha^{-1}) was determined by following formula:

Stem biomass (t ha^{-1}) = Mean volume increment (m^3 ha^{-1})* Wood density (kg $m-^3$)

In order to find out total tree biomass, biomass expansion factor (BEF) was used. Biomass expansion factor for respective tree species was sourced from available literature. BEF ration of 1.51 was used to figure out total tree biomass (Haripriya, 2000; Ahmad *et al*., 2014). The following formula was used to estimate total tree biomass

Total tree biomass (t ha^{-1}) = Stem biomass (t ha^{-1}) * BEF

Estimation of carbon stock: The C stock was assessed from total biomass (t ha^{-1}). For the conversion of total biomass to total carbon stock a conversion factor of 0.5 was used.

Total carbon stock (t ha^{-1}) = Total tree biomass (t ha^{-1})* 0.5

Net annual carbon accumulation in the living biomass: Net carbon accumulation in living tree biomass was assessed from the difference of total carbon gain by biomass and total carbon loss from biomass. The gain loss method of IPCC was used to find out annul accumulation of forest in the biomass of the coniferous forest of the Dir Kohistan (Anon., 2006; Tolunay, 2009). The following formula (Tolunay, 2009) was used for the determination of annual change in carbon stock in the biomass of coniferous forest of the study area.

$$\Delta C_B = (\Delta C_G - \Delta C_L)$$

where ΔC_B is the annual change in the biomass carbon, ΔC_G is the total annual gain in biomass carbon and ΔC_L is the total loss of biomass carbon from the forest in terms of fuel wood, timber wood consumption and illegal cutting.

Results and Discussions

Annual growth: Annual growth (cm) for the respective tree species was calculated from the inventory data of the respective forest division as outlined in working plan. The annual growth for each diameter class from 15 cm to 152 cm (diameter interval 2.54cm) was assessed. The results showed that maximum annual growth occurred in diameter class of 15cm while minimum growth occurred in diameter class of 152 cm for each species (Table 2). It can be seen from the data that among all species, maximum growth of 0.28±0.12 cm yr^{-1} was found in *Pinus wallichiana***,** while the minimum growth was recorded in *Abies pindrow* and was 0.23±0.056 $cmyr^{-1}$.

Mean annual increment (m^3 ha^{-1}), and total accumulation of carbon (t ha^{-1} yr^{-1}) in living tree biomass: Mean Annual increment (m^3 ha^{-1}) was calculated from the present and future stand- Stock Table of the respective tree species of the study area. The mean volume increment (MAI) was 5.07m^3 ha^{-1}. Species wise *Pinus wallichiana* produced more mean annual increment (m^3 ha^{-1}) as compared to other tree species. Similarly total biomass and total carbon stock for each tree species was estimated and the results are presented in Table 2. The results showed that the forest of the study gain 3.39 t ha^{-1} biomass annually while the total area accumulated carbon in the living tree biomass is 1.65 t ha^{-1} yr^{-1}

Table 1. Mean Annual increment (m^3 ha^{-1} yr^{-1}), Total volume increment (m^3 ha^{-1} yr^{-1}) and total wood extracted illegally from the coniferous forest of the study area.

S.No	Total area (ha)	56522.27
1	Average volume increment (m^3 ha^{-1} yr^{-1})	5.07
2	Total volume increment (m^3 ha^{-1} yr^{-1})	288159.1
3	Total fire wood requirement (m^3 ha^{-1} yr^{-1})	223263
4	Total timber requirement (m^3 ha^{-1} yr^{-1})	32217.69
5	Illegal cutting (m^3 ha^{-1} yr^{-1})	2826.114
6	Total wood requirement m^3 ha^{-1} yr^{-1}	258306.8

[a b] Derived from inventory data (working plan for Dir Kohistan 1994-95 to 2014-2015; Ahmad *et al*., 2014)

Table 2. Mean annual growth (cm) of each species.

S.No.	Species	Mean annual growth cm	Min growth cm	Max growth Cm	Std error	CV%
1	*Cedrus deodara*	0.23±0.073	0.11	0.36	0.0099	30.86
2	*Pinus wallichiana*	0.28±0.12	0.078	0.49	0.016	42.97
3	*Abies pindrow*	0.23±0.056	0.142	0.33	0.0075	23.79
4	*Picea smithiana*	0.24±0.061	0.144	0.35	0.0082	24.58

Table 3. Mean annual increment (m^3 ha^{-1}), stem biomass (t ha^{-1}), total biomass (t $ha^{-1} yr^{-1}$) and total C- Stock(t ha^{-1} yr^{-1}).

Species	Mean annual increment m^3 ha^{-1}	Wood density kg m^3	Stem biomass t ha^{-1} yr^{-1}	BEF	Total biomass t $ha^{-1}yr^{-1}$	Total C- Stock t ha^{-1} yr^{-1}
Cedrus deodara	1.19	466	0.55	1.51	0.84	0.42
Pinus wallichiana	1.44	499	0.71	1.51	1.085	0.54
Abies Pindrow	1.18	372	0.43	1.51	0.66	0.33
Picea Smithiana	1.25	382	0.47	1.51	0.72	0.361
Total	5.07		2.19		3.31	1.65

Table 4 . Total loss in Mean annual volume (m^3 ha^{-1}), biomass (t $ha^{-1}yr^{-1}$) C- Stock(t ha^{-1} yr^{-1})

Sources of biomass	Volume m^3 $ha^{-1}yr^{-1}$	Wood density kg m^{-3}	Stem biomass t ha^{-1}	BEF	biomass t $ha^{-1}yr^{-1}$	C- Stock t ha^{-1} yr^{-1}
Removal						
Fuel wood requirement	3.95	429.75	1.69	1.51	2.56	1.28
Timber wood requirement	0.57	429.75	0.24	1.51	0.37	0.18
Illegal cutting	0.05	429.75	0.023	1.51	0.03	0.017
Total	4.58	429.75	1.968		2.97	1.48

Table 5.Net accumulation of carbon in the living tree biomass

Total volume gain m^3 yr^{-1}	288159.1	Total Volume loss m^3 yr^{-1}	258306.8	Net volume gain m^3 yr^{-1}	29852.33
Total Biomass gain tons yr^{-1}	188273	Total Biomass loss tons yr^{-1}	167523.6	Net biomass gain tons yr^{-1}	20749.43
Total Carbon gain tons yr^{-1}	94136.48	T Carbon loss tons	83761.78	Net carbon gain tons yr^{-1}	10374.7

Annual loss of carbon (t ha^{-1} yr^{-1}) due to biomass removal: In present study total loss of carbon from the removal of biomass was determined (excluding loss of carbon occurred from plants and soil respiration). The sources of biomass removal occurred in the form of fuel wood consumption, Timber wood consumption and illegal cutting. All data regarding timber wood consumption, fuel wood consumption and illegal cutting was sourced from the inventory data. Total requirement of the fuel wood and timber for domestic purposes was assessed for the plan period (1994-95 to 2014-15) (Table 1). The average annual wood requirements was calculated for timber and fuel wood. A detail of wood consumption is given in Table 3. The mean wood consumption in study area was 4.58m^3 $ha^{-1}yr^{-1}$. In present study the total loss in biomass was assessed t ha^{-1} yr^{-1}. The sources of biomass loss occurred in study area in the form of fuel wood, timber wood consumption and illegal cutting. The total estimated biomass removal was assessed at 2.97t $ha^{-1}yr^{-1}$. The total calculated carbon loss from the living tree biomass was 1.48t ha^{-1} yr^{-1}

Net accumulation of carbon in the living tree biomass: Net accumulation of carbon was estimated from the difference of total carbon gain by the coniferous forest and total carbon loss. The total area of the coniferous forest in the study area is 56822.27 ha. The mean biomass gain by the forest of the study area is 3.31t $ha^{-1}yr^{-1}$ (Table 3), while the biomass removal from the coniferous forest of the study area is 2.97t $ha^{-1}yr^{-1}$ (Table 4). The net biomass gain by the forest each year is 0.34 t ha^{-1}. Details are presented in Table 5. The mean carbon stock accumulated in the living biomass of the coniferous forest is 1.65 t $ha^{-1}$and the total loss of carbon from the removal of biomass is 1.48 t ha^{-1} (Table 4). The net carbon that is gain by the forest each year is 0.17 t ha^{-1} and the total net carbon gain by the entire region is 10374.7 t yr^{-1}.

Discussions

The present study describes net annual accumulation of carbon stock in the living biomass of the coniferous forest of Dir Kohistan. To estimates net annual accumulation of carbon in the coniferous forest inventory data was used. The present study concluded a mean volume increment of 5.07m^3 $ha^{-1}yr^{-1}$ this value gives slight greater estimate from the value of

$3.14m^3$ $ha^{-1}yr^{-1}$ reported by Tolunay (2011) from Turkey. Annual carbon losses and gain from the forest was estimated from the total biomass gain and biomass loss from the forest. The present study described a total gain of 3.31 t $ha^{-1}yr^{-1}$ biomass which is in the range of biomass value of 1.5 to 5 t $ha^{-1}yr^{-1}$ reported by Anon., (2003) for subtropical mountain ecosystem for continental Asia. In present study total annual accumulation of carbon stock in the living biomass was calculated at1.65 t $ha^{-1}yr^{-1}$ which is consistent with the study of Hunt *et al*., (2010) who reported annual carbon accumulation of 0-8 to 2.8 t C yr^{-1} ha^{-1} from the managed conifer forest in northern Ontario. However, the results of present study recorded lower estimate of carbon accumulation in living biomass as compared to the study of Sharma & Rai (2007) who reported an annual carbon of 4.71 to 6.57 t C ha^{-1} yr^{-1} from the temperate forest of Sikkim Himalaya.

The present study also revealed total carbon loss due to biomass removal due to illegal cutting biomass burning and wood use as a timber. The results showed (Table 4) that a total of 1.48 t C yr^{-1} ha^{-1} is removed from the forest in terms of fuel wood, timber utilization and illegal cutting. Out of total carbon removed annually 86.46 percent (1.28t C ha^{-1} yr^{-1}) is removed in terms of fuel wood while the share of timber and illegal cutting in the annual loss of carbon is 12.16%(0.18 t C ha^{-1} yr^{-1}) and 1.38% (0.017 t C ha^{-1} yr^{-1}). The mean carbon removal of 1.48 t C ha^{-1} yr^{-1}falls within the rage reported by Sharma & Rai (2007). The present study also accounts net carbon gain by the forest each year. The results showed that the coniferous forest of the region gain net 0.17 t C ha^{-1} yr^{-1} each year these results are corroborated by the findings of Kaula *et al*., (2009).

Carbon accumulation in the forest and its removal from the forest depends upon the stock carbon in vegetation and rate of deforestation (Sharma & Rai, 2007). The coniferous forest of Pakistan is declining at the rate of 1.27 percent yr^{-1} since the base year of 1992 (Sheikh, 2012). The socio-economic condition of the local people is very poor. People of the study area depend mostly for fuel wood, timber and livestock grazing on forest. The local people also cut the forest for agriculture purposes. The burden on forest increases day by day due to population increase, even the remote area of the region is occupied by the people. Due to above factors net biomass carbon gain by the forest was estimated low (0.17 t C ha^{-1} yr^{-1}).

Forest is the major carbon sink and the biomass accumulates large amount of carbon due to its woody character (Houghton, 2005; Anon., 2006, Sharma *et al*., 2011). Afforestation, and control of deforestation and increasing forest area can significantly reduce the level of CO_2 (Ahmad *et al*., 2014; Sharma *et al*., 2001; Tolnnay *et al*., 2009; Watson, 2000). Through afforestation and control of deforestation the potential of study area can be increase to sinks more carbon from their present potential of 10374.7 t yr^{-1}.

Conclusion

The study area has great potential to store and remove atmospheric carbon through appropriate measures. Increasing forest area through plantation campaigns, control of deforestation, encouraging Agro forestry practices are the agents that can enhance the ability of forest to sink more carbon. Alternate production of energy like Hydro power and solar energy can significantly reduce the pressure on forest in terms of fuel wood removal. These suitable measures can result in the inclusion of study area in the carbon trading under CDM and REDD++.

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