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Assessment of *Pinus gerardiana* carbon stock in Chilgoza Forest of Suleiman Range, Pakistan

Pervez Manan*, Farhat Jabeen

National REDD Office, Ministry of Climate Change, Islamabad, Pakistan

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Abstract

Forests absorb 2.6 billion tons of carbon dioxide annually almost about one-third of that released annually by burning fossil fuels. But this great storage system also means that cutting down forests have great impact. *Pinus gerardiana* is known for its high value edible seeds (nuts) locally called as "Chilghoza". As the potential economic benefits of Chilghoza to local livelihoods is worth billions of rupees annually thus economic importance is always given priority and its most important role of the maintenance and protection of vital ecosystem services is undermined. Climate Change is the biggest threat to humanity and ecosystems. The forestry sector has been recognized as the most important climate change mitigation option and the mechanism of REDD+ has been developed under the United Nations Framework Convention on Climate Change, for which forest carbon stock assessments and monitoring is essential. Therefore, this study was conducted to ascertain the carbon stock of *Pinus gerardiana* at the landscape level. The study concluded that a total carbon stock of *Pinus gerardiana* in the study area was 170772.854t with an average density of 9.195461t/ha. In the study area, higher percentage of the trees were in sub-mature and young stages thus having a high potential for REDD+ as generally the growth rate in these stages is fast and they can sequester a large quantity of carbon dioxide. The findings of the study will be helpful in preparation of forest management plans and in developing REDD+ projects.

***Corresponding Author:** Pervez Manan ✉ pervezmanan@gmail.com

Introduction

Forests absorb 2.6 billion tons of carbon dioxide each year equivalent to about one-third of that released by burning fossil fuels annually. But this great storage system also means that when forests are cut down, the impact is big. Deforestation contributes about 20% of the global Green House Gasses (GHG) emissions. Similarly the removal capacity of forests is decreased as forests are lost (Y, Pan *et al.*, 2011). Traditionally forests are always considered in-terms of their economic benefits or timber and fuelwood production ignoring the environmental services it is providing to the humanity and ecosystems, particularly climate change mitigation.

Pinus gerardiana is known for its high value edible seeds (nuts), locally called as "Chilghoza", rich in carbohydrates and proteins. It is native to the north-western Himalaya and is distributed in eastern Afghanistan, northern Pakistan and north-western India, growing at altitudes ranging between 1800 and 3300m. It is often associated with the Blue pine (*Pinus wallichiana*) and Deodar (*Cedrus deodara*). In Pakistan these forests are mainly located in the dry temperate zone of the Hindukush-Karakoram-Himalaya region i.e Sherani Area (Suleiman range) on the border between Baluchistan and Khyber Pakhtunkhwa (KP), South Waziristan, Chitral, Gilgit Baltistan and Azad Jamu & Kashmir (Sherani, SH., and Urooj R. 2019).

As the potential economic benefits of Chilghoza to local livelihoods is worth billions of rupees annually thus economic importance is always given priority and its most important role of the maintenance and protection of vital ecosystem services (e.g. carbon storage and climate change mitigation, soil and flood protection, wildlife habitat, water recharge, watershed conservation and water flow regulation, fodder, etc) are still not accounted properly.

Forests play a major role in the carbon cycle globally as they account for a greater part of the carbon exchange between the atmosphere and terrestrial biosphere than any other ecosystem (Lal, R 2003). The world's forests have been estimated to contain up to 80% of all aboveground carbon and 40% of all belowground (soils, litter, and roots) terrestrial carbon (Dixon *et al.*, 1994). Forest ecosystem biomass estimation is important for assessing the productivity and sustainability of the forest. It also gives us an idea of the potential amount of carbon emissions in the form of carbon dioxide when forests are being cleared or burned (Lu, D 2006).

There are many models developed for the estimation of biomass and carbon (Mbow *et al.*, 2013), some of these models are species specific while others are generalized in their application. General equations can be inaccurate when used to estimate biomass of individual tree species as compare to species-specific allometric equations which are more accurate and precise, and are, therefore, recommended for estimating the biomass of highly valued species (Litton, Kauffman 2008). This requires that appropriate allometric models specific for a given forest type are in place (Molto *et al.*, 2013). Allometric models use the easy to measure individual tree parameters such as DBH and total tree height from forest inventories to estimate volume aboveground biomass.

Pakistan is in the readiness phase of implementing REDD+ (Reducing emission from Deforestation, Forest Degradation, Sustainable Forest Management, Conservation of Forest Carbon Stock and Enhancement of Forest Carbon Stock) since 2011 (REDD+ Pakistan). REDD+ is considered as one of the viable options for climate change, forestry resources conservation, and alleviating poverty of associated communities (Ngo *et al.*, 2013). It has been identified as one of the most economically feasible mitigation options (Stern, 2007). For REDD+ initiatives forest carbon stock assessments and monitoring is essential. Therefore, this study has been conducted to ascertain the carbon stock of *Pinus gerardiana* at the landscape level.

Material & methods

Study Area

Suleiman Range contains the world's largest pure stand of Chilghoza (*Pinus gerardiana*) spread over an area of 26000 Hectares. This pure stand of Chilghoza forests straddles the border of southeastern Balochistan and Khyber Pakhtunkhwa Provinces of Pakistan (31° – 36' North and from 69° – 59' East) (Fig-1). With an altitudinal range of 500 - 3,441 meters, the precipitous mountainous terrain of the area with arid climate provides suitable climatic and topographical conditions for the growth of the pure Chilghoza forest. Mean maximum day temperatures range from about 37°C in June to about 13°C in January. Rainfall is scarce (320mm per year), varies with altitude and is highest during the winter season. Chilghoza Forest proprietary rights rest with the Sherani tribe living on both sides of the provincial borders. The Sherani dwelling in Balochistan are called Bargha Sherani whereas those on the KP side are called Largha Sherani. As a tradition, all the tribal people living in the area have equal ownership rights over the available resources. Due to the absence of land settlement in the tribal area, all the ownership record is in the memories of local people (Hussain, S. K, 2015).

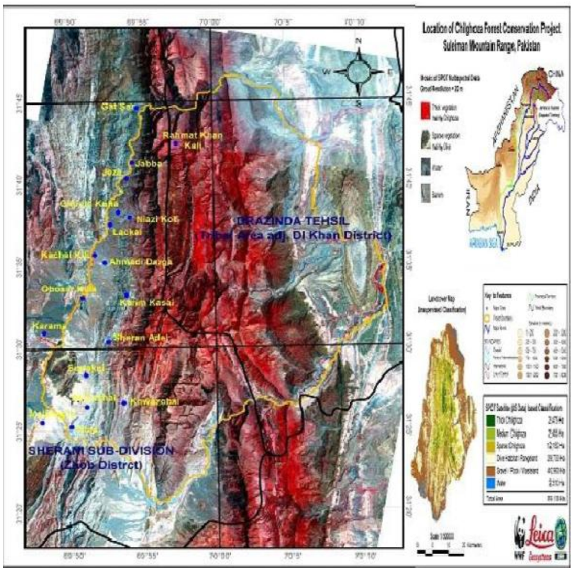

Fig 1. Map of the study area (Source: WWF- Pakistan).

Data Collection and Analysis

Systemic sampling approach was adopted, by dividing the total area into 26 units on map, each unit of 100 ha and taking sample plots in the center of each unit, thus overall 26 plots were sampled. Geographic coordinates of the center of each plot from the map were recorded and were used for navigation into the sample plots in the field. The circular plots with a radius of 17.84 (0.1 Ha area) were used. In each plot, diameters at breast height (DBH) and height of trees with DBH more than 4 cm were measured. The DBH were measured with the help of a diameter tape at 1.3 m above the ground level, while heights were measured with the help of Haga altimeter.

Above-ground dry Biomass inkg per 0.1ha was calculated at plot level by using the following equation (Ali.A, 2015):

$AGB = 0.0253D^{2.6077}$ (1)

Where AGB is above-ground dry biomass in Kilogram (Kg) and D is DBH in cm. to obtain per hectare value the plot level AGB was multiplied by 10.

While, below-ground biomass (BGB) default values of root-shoot ratio were used (IPCC guidelines-2006).

To obtain mean total dry biomass per ha, mean value for AGB and BGB per hectare were added. While mean total dry biomass inkg per ha was multiplied by 26000 to obtained total dry biomass for the whole study area.

Carbon stock (C) inkg was calculated by the following equation (Ali.A, 2015):

$C= 0.47M$ (2)

Where, M is dry biomass.

In both Biomass and Carbonkg were converted to Tonne (t) by dividing it by 1000.

Results and discussion

There were a total of 757353 numbers of trees on 26000 Ha of the study area thus having a density of 29 trees/ Ha whereas forest density reported by Hussain, S. K, 2015, was 27 trees per hectare thus both values are very close, the slight difference may be due selection of 4 cm DBH in this study as compare to 16 cm DBH in previous study. The tree stocking density is quite low and there exist scope for enhancement of the carbon stock through assisted natural regeneration activities.

As illustrated by Table 1 the highest percentages of trees are in sub-mature (59%) and Young Stage (34%)

whereas only 7% of trees are in mature stage, thus having a high potential for REDD+ as generally the growth rate in these stages is fast and they can sequester a large quantity of carbon dioxide.

Table 1. Development Stages of *Pinus gerardiana*.

Development stage (Diameter)	No. of Trees	Percentage (%)
Young (below 30 cm)	255576	34
Sub-mature (30 to 60 cm)	446707	59
Mature (above 60 cm)	55070	7
Total	757353	100

As shown in Table 2 this study found the above-ground dry biomass as 363346498.7kg or 363346.5 t with above-ground dry biomass density of 1397.49kg/ha or 13.9749 t/ha in the study area and average above-ground biomass per tree of 479.75845kg/tree or 0.47976 t/tree.

Table 2 shows that total dry biomass was 508685098kg or 508685 t with biomass density of 19564.81kg/ha or 19.56481t/ha in the study area and average biomass per tree of 671.66kg/tree or 0.67166t/tree.

Table 2. Dry Biomass.

Average Above Ground Dry Biomass per tree		Total Above Ground Dry Biomass		Average Above Ground Dry biomass Density		Total Below Ground Dry Biomass		Total Average Dry Biomass Per tree		Total Dry Biomass		Total Average Dry Biomass Density	
Kg/tree	t/tree	Kg	T	Kg/ha	t/ha	Kg	t.	Kg/tree	t/tree	Kg	t	Kg/ha	t/ha
479.75845	0.47976	363346498.7	363346.5	1397.49	13.9749	145338599	145338.6	671.66	0.67166	508685098	508685	19564.81	19.56481

Table 3 shows that total above-ground (ABG) carbon stock was 170772854kg or 170772.854 t with above-ground carbon density of 6568.18kg/ha or 6.5682t/ha and average above-ground carbon stock per tree of 225.48kg/tree or 0.2255t/ tree. To compare this study there does not exist any specific research work on Pinus gerardiana carbon stock assessment explicitly; however we compared these findings with the results of Ali. A, 2017 in context of dry temperate forests, according to which the ABG carbon density in those forests is 0.2395 t/tree which is very close to the findings of this study i.e. 0.2255t/tree. Whereas according to Ali, A, 2017 ABG carbon density in the dry temperate forests of Khyber Pakhtunkhwa (KP) is 99.41t/ha which is too high as compare to findings of this study i.e. 6.5682t/ha it is due to a higher tree stocking density of 415trees /ha as well as inclusion of shrub/sapling carbon stock in the ABG carbon.

Table 3. Carbon Stock.

Average Above Ground Carbon per tree		Total Above Ground Carbon		Average Above Ground Carbon Density		Total Below Ground Carbon		Total Average Carbon Per tree		Total Carbon Stock		Total Average Carbon Stock Density	
Kg/tree	t/tree	Kg	t	Kg/ha	t/ha	Kg	t	Kg/tree	t/tree	Kg	t	Kg/ha	t/ha
225.48647	0.2255	170772854	170772.854	6568.18	6.5682	68309141.6	68309.14	315.68	0.31568	239081996	239082	9195.46	9.19546

Table 3 shows that total carbon stock was 239081996kg or 239082 tons with carbon density of 9195.46kg/ha or 9.195461t/ha and average carbon stock per tree of 315.68kg/tree or 0.31568 t/tree.

Conclusion

The total carbon stock of *Pinus gerardiana* in the study area has been estimated 170772.854t with an average density of 9.195461t/ha. The tree stocking density is quite low and the carbon stock could be enhanced through assisted natural regeneration activities. In the study area, higher percentage of the trees were in sub-mature and young stages thus having a high potential for REDD+ as generally the growth rate in these stages is fast and they can sequester a large quantity of carbon dioxide.

To the extent of my knowledge, the study was the first attempt for quantifying the carbon stocks of the *Pinus gerardiana* in the Chilgoza forest of Suleiman Range. The data will be helpful in preparation of forest management plans, developing of REDD+ projects, and future studies.

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