



Research Article

Comparative Assessment of Carbon Stocks in Guzara and Reserved Forests of Siran Valley, Mansehra, Khyber Pakhtunkhwa

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Abstract | A study was conducted in Moist Temperate Forests of Siran Valley of District Mansehra, Khyber Pakhtunkhwa to estimate and compare carbon stocks in Guzara and Reserved Forests. Data was collected from 253 sample plots using a systematic random sampling technique. The total carbon stock in the study area was estimated as 1,374,702 tonnes. Out of this, 56% is in the soil, 33 % in aboveground biomass, 9% in belowground biomass and 2% in litter. Average carbon density was estimated as 100 t/ha in the landscape. Mean aboveground carbon density was determined at 33.60 t/ha. In Reserved Forest the aboveground carbon stock is 42.29 t/ha whereas in Guzara Forests, this carbon is 27.20 t/ha. Similarly, belowground carbon stock in the landscape was estimated as 9.74 t/ha. Litter carbon was estimated as 1.97 t/ha and organic soil carbon was estimated at 55.47 t/ha. Carbon density is higher in all pools of Reserved Forests as compared to Guzara Forest. Carbon density in the reserved forest is 115.51 t/ha and Guzar Forest is 91.88 t/ha. This difference between Guzara and Reserved Forests is due to the fact that Guzara Forests have been severely degraded as these are used for meeting the timber and fuelwood requirements of the local community due to which biomass carbon stock has been significantly reduced. The study recommends to conserve and develop these forests through initiation of a REDD+ Project with active community participation. It is also recommend to stop open grazing and illicit cutting for the rehabilitation of these valuable forests.

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Keywords | Biomass, Carbon, Forest, Guzara, Reserved, Temperate



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Introduction

Forests play an important role in climate change mitigation as they sequester a large amount of carbon dioxide from the atmosphere. However, when forests are cut, the carbon stored

in the biomass and soil is released back into the atmosphere. Thus, conservation and development of forests are crucial for addressing the challenge of climate change (Brown, 2002; FAO, 2006). Besides, trees are renewable natural resources and have a high potential in contributing to transition to

fossil-free energy systems (Baker *et al.*, 2010). Due to this crucial role, forests are on the top of global environmental agenda.

Reducing emissions from deforestation and forest degradation commonly titled as REDD+ has emerged as a promising option for climate change mitigation in forestry sector (Scheyvens, 2010). The idea of REDD+ is to reward those nations and communities who protect and develop forests and thus contribute in reducing carbon emissions. One of the key requirements for participation in REDD+ Programme and other carbon trading schemes is measurement and monitoring of forest carbon stocks (UNFCCC, 2010). Consequently, forest carbon stock assessment has been started in many countries.

Khyber Pakhtunkhwa is the most forested province of Pakistan with about 20% forest cover. These forest are mostly located in Hazara and Malakan Forest Regions of the province. Mansehra District is situated in Hazara Forest Region with 149,454 ha forest area. Forest types of Mansehra include subtropical broad-leaved evergreen forests, subtropical pine forests, moist temperate forests, dry temperate forest and subalpine forests (Bukhari *et al.*, 2012). There are three forest divisions in District Mansehra including, Siran Forest Division, Kaghan Forest Division and Agror-Tanawal Forest Division. Siran Forest Division comprises Siran Valley which has subtropical Pine Forests and Himalayan Moist Temperate Forests. On the basis of legal status, these forests can be categorized as Guzara forests and reserved forests.

Reserved forests are exclusively owned by the state and are generally without rights and concessions. On the other hand, Guzara forests are owned by local community either individually or jointly and managed by the Forest Department (GoKP, 2002). Guzara forests are meant for meeting the timber and fuelwood requirements of the local community. Guzara Forests are generally more degraded than Reserved Forests due to the reasons that these are used for meeting the requirements of the local community (Azhar, 1989).

Sustainable Forest Management (SFM) Project is a joint venture of the Ministry of Climate Change (MoCC), GEF and UNDP and which is being implemented in the selected landscapes of Punjab, Sindh and Khyber Pakhtunkhwa. The main objective of this project is to promote sustainable forest management in

Pakistan's Western Himalayan Temperate Coniferous forests, Sub-tropical broadleaved evergreen thorn (Scrub) forests and Riverine forests for biodiversity conservation, mitigation of climate change and securing of forests ecosystem services (UNDP, 2016). A study was conducted under SFM Project to estimate and compare carbon stocks in Guzara and Reserve Forests in the SFM Project landscape of Siran Valley and recommend measures for conservation and enhancement of carbon stocks in these forests.

Materials and Methods

Field survey for carbon stock assessment in Guzara and Reserve Forests of Siran Valley was conducted during May–November, 2018. A systematic random sampling technique was used for collecting data in the field. Sample plots were laid out on geo-referenced maps of the forests using a grid of 500x500 m (Figure 1). The coordinates of the centers of the sample plots were noted from the maps and uploaded onto GPS and navigated in the field accordingly.

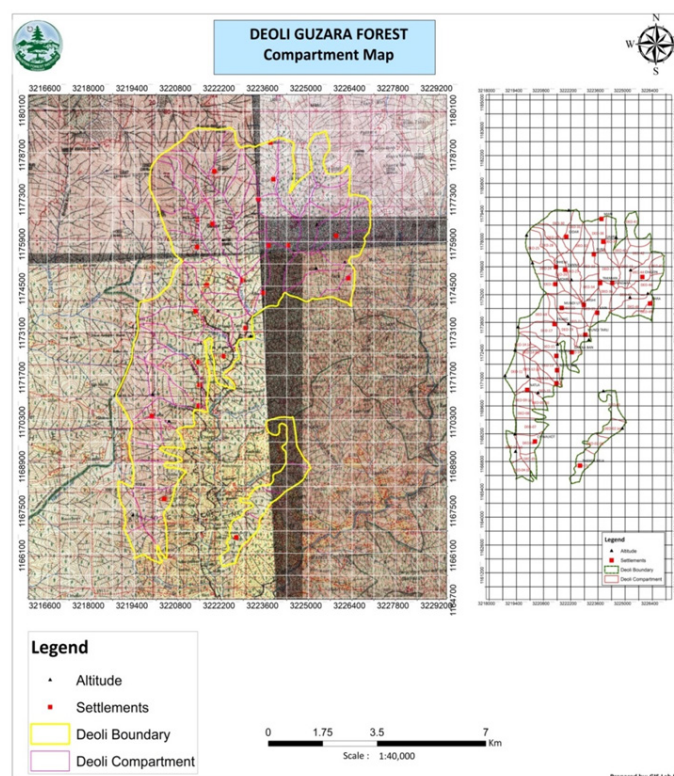


Figure 1: Location of sample plots in Devli Guzara.

As the study is aimed at estimating biomass and carbon stock in different carbon pools of moist temperate forests, nested circular plot approach was applied for collecting the data. As illustrated in the Figure 2, three subplots were established within each plot for specific purposes. The outermost circular plot

with radius 17.84m was used for measurement of trees. The second circular plot with radius 5.64 m was used for measurement of shrubs and sapling; and the innermost plot with radius of 0.56 m was used for measurement of leaf/litter and grasses as well as soil (Subedi *et al.*, 2010). Locally developed allometric equations were used to convert forest inventory data into biomass and carbon stocks (Ali, 2020; Chave *et al.*, 2005).

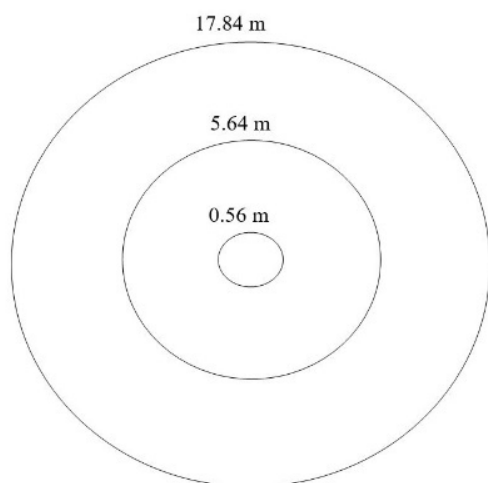


Figure 2: Nested circular plot.

Data was collected from 253 sample plots, out of which 93 sample plots were laid out in Reserved Forests and 160 were in Guzara forests. The distribution sample plots in different forest areas are given in Table 1.

Table 1: Distribution of sample pots in different forest areas.

| Forest area | Forest area (ha) | Number of sample plots |
|-----------------------------|------------------|------------------------|
| Panjul reserved forest | 2,482 | 46 |
| Unna reserved forest | 2,249 | 47 |
| Deoli guzara forest | 5,028 | 87 |
| Jachha guzara forests | 1,330 | 29 |
| Manda guchha guzara forests | 2,655 | 44 |
| Total | 13,744 | 253 |

Results and Discussion

Aboveground biomass carbon stock

Aboveground biomass comprises trees and shrubs and it is the most important pool of carbon in a forest ecosystem. The above ground carbon stock in the study area was estimated at 445,698 ton. Aboveground carbon stock was determined at 33.60 tonnes per ha. In reserved forest the above ground carbon stock is

42.29 t/ha and in Guzara Forest, the aboveground carbon density was calculated at 26.32 t/ha (Table 2). Thus, the aboveground carbon density is much higher in reserved forests as compared to Guzara forests. The aboveground carbon stock in the study areas is less than the average carbon density found in other moist temperate forests of Khyber Pakhtunkhwa which is 85 t/ha (Ali *et al.*, 2019). This is due to the fact that the forests of the study area are more degraded than other forest areas. In the reserved forest, the total aboveground carbon stock is 203,308 tonnes whereas in Guzara forest the total aboveground carbon stock is 242,390 tonnes. The detail is given in the Table 3.

Table 2: Aboveground carbon stock densities in different forest areas.

| Forest category | Forest area | AGTC (t/ha) | AG Shrub carbon (t/ha) | AGC (t/ha) |
|-----------------|-----------------------------|-------------|------------------------|------------|
| Reserved forest | Panjul reserved forest | 49.61 | 0.77 | 50.38 |
| | Unna reserved forest | 34.13 | 0.67 | 34.80 |
| Average | | 41.57 | 0.72 | 42.29 |
| Guzara forests | Deoli Guzara forest | 26.30 | 0.41 | 26.71 |
| | Jachha Guzara forests | 28.32 | 0.98 | 29.29 |
| | Manda Guchha Guzara forests | 25.07 | 0.97 | 26.04 |
| Average | | 26.32 | 0.88 | 27.20 |
| Overall average | | 32.80 | 0.80 | 33.60 |

Table 3: Distribution of aboveground carbon stock.

| Forest category | Forest area | Forest area (ha) | AGC (t/ha) | Aboveground carbon stock (tonnes) |
|-----------------|-----------------------------|------------------|------------|-----------------------------------|
| Reserved forest | Panjul reserved forest | 2,482 | 50.38 | 125043.2 |
| | Unna reserved forest | 2,249 | 34.80 | 78265.2 |
| Average | | 4,731 | 42.29 | 203,308 |
| Guzara forests | Deoli Guzara forest | 5,028 | 26.71 | 134297.9 |
| | Jachha Guzara forests | 1,330 | 29.29 | 38955.7 |
| | Manda Guchha Guzara forests | 2,655 | 26.04 | 69136.2 |
| Average | | 9,013 | 27.20 | 242,389.8 |
| Overall average | | 13,744 | 33.60 | 445,698.1 |

Belowground biomass

Carbon in the belowground biomass in coniferous forests of Siran Valley was taken as 29% of the aboveground biomass (IPCC, 2007). Mean belowground biomass was estimated at 9.74 t/ha. The total below ground carbon was estimated at 127,800 tonnes. Detail of carbon stock in belowground biomass in different forest areas is given in the Table 4.

Table 4: Distribution of below-ground carbon stock.

| Forest category | Forest area | Forest area (ha) | BGC (t/ha) | Belowground carbon stock (tonnes) |
|-----------------|-----------------------------|------------------|------------|-----------------------------------|
| Reserved forest | Panjul reserved forest | 2,482 | 14.61 | 36262.02 |
| | Unna reserved forest | 2,249 | 10.09 | 22692.41 |
| Average | | 4,731 | 12.26 | 58954.43 |
| Guzara forests | Deoli Guzara forest | 5,028 | 7.46 | 37508.88 |
| | Jachha Guzara forests | 1,330 | 8.49 | 11291.7 |
| | Manda Guchha Guzara forests | 2,655 | 7.55 | 20045.25 |
| Average | | 9,013 | 7.89 | 68845.83 |
| Overall average | | 13,744 | 9.74 | 127,800.26 |

Litter carbon

Litter is also an important pool of carbon in coniferous forest ecosystem as a lot of biomass accumulates on the forest floor due to needle fall. This layer protects the soil against erosion and provide habitat to soil organisms which keep the soil porous and decompose the organic matter. However, sometimes it becomes cause of forest fire. The total carbon stock in the litter pool was estimated at 27,050 tons with mean of 1.97 t/ha. Average litter carbon in the reserved forests was estimated as 2.48 t/ha and in Guzara forests as 1.70 t/ha (Table 5). The litter carbon density of reserved forests is more than that of the Guzara forests.

Table 5: Estimates of carbon stocks in litter in different forest areas.

| Forest category | Forest area | Forest area (ha) | Litter C (t/ha) | Litter carbon stock (tonnes) |
|-----------------|-----------------------------|------------------|-----------------|------------------------------|
| Reserved forest | Panjul reserved forest | 2,482 | 2.19 | 5,435 |
| | Unna reserved forest | 2,249 | 2.80 | 6,297 |
| Average | | 4,731 | 2.48 | 11,733 |
| Guzara forests | Deoli Guzara forest | 5,028 | 1.95 | 9,805 |
| | Jachha Guzara forests | 1,330 | 1.25 | 1,662 |
| | Manda Guchha Guzara forests | 2,655 | 1.45 | 3,850 |
| Average | | 9,013 | 1.70 | 15,317 |
| Overall average | | 13,744 | 1.97 | 27,050 |

Soil organic carbon

Soil samples were collected from different forest areas of Siran Valley up to 30 cm depth. The average soil bulk density was found as 0.62 g/cm³ showing that the soil is porous, loamy and non-compact. Mean soil organic matter was found as 5.25% in the forest

area. Average organic soil carbon was estimated at 55.47 t/ha. This level of soil organic carbon is closer the findings of Ali *et al.* (2019) who reported soil organic carbon as 60 t/ha in Moist Temperate Forests of Khyber Pakhtunkhwa. In Reserve Forests, the soil organic carbon was 56.20 t/ha whereas in Guzara forest, the average soil carbon was 54.65 t/ha (Table 6). Though there is no significant difference between Guzara and reserved forests in terms of soil organic carbon, the reserved forests have more soil carbon than the Guzara forests.

Table 6: Estimates of carbon stocks in litter in different forest areas.

| Forest category | Forest area | Forest area (ha) | SOC (t/ha) | Soil carbon stock (tonnes) |
|-----------------|-----------------------------|------------------|------------|----------------------------|
| Reserved forest | Panjul reserved forest | 2,482 | 57.60 | 142963 |
| | Unna reserved forest | 2,249 | 55.50 | 124820 |
| Average | | 4,731 | 56.55 | 267783 |
| Guzara forests | Deoli Guzara forest | 5,028 | 54.65 | 274780 |
| | Jachha Guzara forests | 1,330 | 55.20 | 73416 |
| | Manda Guchha Guzara forests | 2,655 | 54.40 | 144432 |
| Average | | 9,013 | 54.75 | 492,628 |
| Overall average | | 13,744 | 55.47 | 760,411 |

Total carbon stock in the landscape

The total carbon stock in the SFM Project area of Siran Forest Division was estimated at 1,374,702 tonnes with an average of 100 t/ha. Out of this, 56% is in the soil, 33 % in aboveground biomass, 9% in belowground biomass and 2% in litter (Figure 3). Distribution of carbon stocks in various pools in different forest areas is given in Table 7.

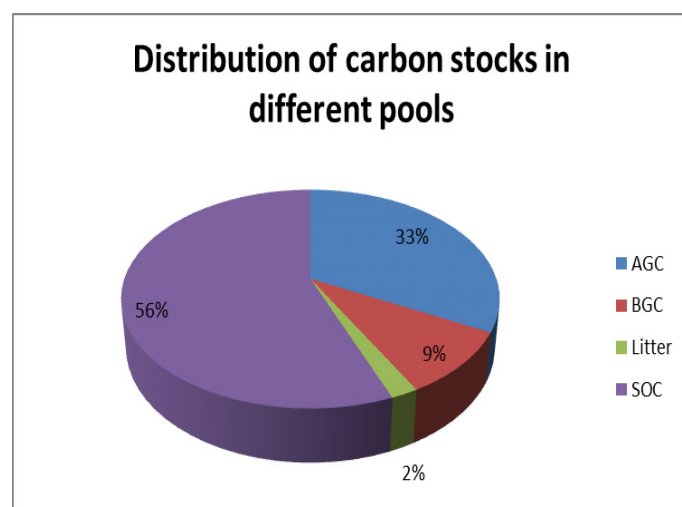


Figure 3: Distribution of carbon stocks in different pools.

Table 7: *Distribution of carbon stocks in different pools and forest areas.*

| Forest category | Forest area | Forest area (ha) | AGC tonnes | BGC tonnes | Litter C tonnes | SOC tonnes | Total C (tonnes) | C density (t/ha) |
|-----------------|-----------------------------|------------------|------------|------------|-----------------|------------|------------------|------------------|
| Reserved forest | Panjul reserved forest | 2,482 | 125043 | 36262 | 5,435 | 142963 | 312,185 | 125.78 |
| | Unna reserved forest | 2,249 | 78265 | 22692 | 6,297 | 124820 | 234,323 | 104.19 |
| Guzara forests | Deoli Guzara forest | 5,028 | 134298 | 37509 | 9,805 | 274780 | 461,420 | 91.77 |
| | Jachha Guzara forests | 1,330 | 38956 | 11292 | 1,662 | 73416 | 126,656 | 95.23 |
| | Manda Guchha Guzara forests | 2,655 | 69136 | 20045 | 3,850 | 144432 | 240,118 | 90.44 |
| Total | | 13,744 | 445698 | 127800 | 27049 | 760411 | 1,374,702 | 100.02 |

Conclusion and Recommendations

Moist temperate forests of Siran valley have high potential for storing carbon. However, these forest are currently in a degraded for due to which their current carbon stock is much lower than the potential. The total carbon stock in the study area is 1,374,702 tonnes. Out of this 56% is in the soil, 33% in aboveground biomass, 9% in belowground biomass and 2% in litter. Average carbon density was estimated as 100 t/ha in the landscape.

The total above ground carbon stock in the study area was estimated at 445698 tonnes. Mean aboveground carbon density was determined at 33.60 t/ha. In Reserved Forest the aboveground carbon stock is 42.29 whereas in Guzara forests, this carbon is 27.20 t/ha. Similarly, belowground carbon stock in the landscape was estimated as 127800 tonnes with average of 9.74 t/ha. Litter carbon was estimated as 27,049 tonnes with average of 1.97 t/ha. Dead wood was found to be a non-significant pool of carbon in the study area. Average organic soil carbon was estimated at 55.47 t/ha and the total soil organic carbon was estimated at 760,411 tonnes.

It was found that carbon density is higher in all pools of reserved forests as compared to Guzara forest. Carbon density in the reserved forest is 115.51 t/ha and Guzar forest is 91.88 t/ha. This difference between Guzar and reserved forests is due to the fact that Guzara forests have been severely degraded as these are used for meeting the timber and fuelwood requirements of the local community. Even the reserved forests are not in an ideal condition in terms of carbon stock because these forests are also subjected to severe anthropogenic pressure and illicit cutting due to which biomass carbon stock has been significantly reduced.

It is recommended that effective steps may be taken

for stopping the illicit cutting and degradation of both Guzara and reserved forests with active participation of the Guzara owners and local communities. Reforestation and assisted natural regeneration programs may be also be initiated on urgent basis for the rehabilitation of these valuable forests. Open grazing and illicit cutting are the major threats to these forests which must be controlled through community organization. Introduction of a REDD+ Project to compensate the Guzar owners and local community may also help in forest conservation.

Acknowledgement

The authors would like to acknowledge the financial support of the Sustainable Forest Management Project of MoCC and UNDP for conduct of this study. The technical assistance provided by staff of GIS Section and Forest Mensuration Branch of PFI are also acknowledged.

Novelty Statement

Guzara and Reserved Forests are two categories of forests in Khyber Pakhtunkhwa which have different management regimes. The current study is the first ever attempt to quantify and compare carbon stocks in the two forest categories which have the potential for carbon credits generation.

Author's Contribution

Anwar Ali: Conception of idea, devising methodology and original draft writing.

M. Ayaz Khan: Data collection, validation and review.

Nowsherwan Zarif: Formal analysis, data curation, review and editing.

Conflict of interest

The authors have declared no conflict of interest.

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