Ministry of Climate Change

Carbon Stock Assessment in Scrub Forests of Chakwal, Punjab

SUSTAINABLE FOREST MANAGEMENT PROJECT
MINISTRY OF CLIMATE CHANGE
GOVERNMENT OF PAKISTAN
2018

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By

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TABLE OF CONTENTS

List of Acronyms

AGC	Aboveground Carbon
AGTB	Aboveground Tree Biomass
AGTC	Aboveground Tree Carbon
AGM	Aboveground Biomass
BGC	Belowground Carbon
cm	Centimeter
C	Carbon
CO_2	Carbon dioxide
CV	Coefficient of Variation
DBH	Diameter at Breast height
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GHG	Green House Gases
GIS	Geographic Information System
GPS	Global Positioning System
ha	hectare
IPCC	Inter-governmental Panel on Climate Change
m	Meter
mm	millimeter
MRV	Measurement, Reporting and Verification
PFI	Pakistan Forest Institute
REDD+	Reducing Emissions from Deforestation, Forest Degradation, sustainable forest management, conservation and enhancement of forest carbon

SFM	Sustainable Forest Management
UNFCCC	United Nations Framework Convention on Climate Change

SUMMARY

Subtropical broad-leaved forests of Salt Range, District Chakwal is one of the two landscapes selected by Sustainable Forest Management Project in Punjab province. The landscape comprises of sub-tropical broadleaved evergreen thorn (scrub) forests. The total area of the landscape under forest is 20,000 ha, out of which 7,859 ha is forested and owned by the state, and 6,672 ha in the outer landscape is private land, including cultivation (1,752 ha) and pastures and settlements 5,469 ha over communal lands. The forest area is state owned comprising of Diljabba Reserved Forest (2,280 ha), Parerah Reserve Forest (1,309 ha) and Ara Reserve Forest (4,270ha).

Carbon stock assessment in the scrub forests of the landscape including Ara Reserved Forests, Diljabba Reserved Forests and Parerah Reserved Forest was conducted during 2018. Data was collected from 255 sample plots using a systematic random sampling technique. A pre-defined grid of 500x500 m was laid out on the map of each forest and the geographic coordinates of the intersections of the grids were recorded and upload onto GPS devices (Etrix 30). The sample plots were navigated with the help of GPS and maps of the forests. When reach at the sample plot location, the centres of the sample plots were determined and iron rods were inserted in the centres to find out the plots in future. Data was collected on aboveground tree biomass, shrub biomass, litter, dead wood and soil organic carbon using a nested circular plot approach as explained in the preceding section. Below ground biomass was determined using root-shoot ratios from IPCC Guideline 2006.

Olea ferruginea and *Acacia modesta* are the dominant tree species in the landscape. About 63% of the total trees belong to *Olea ferruginea*, 29% belong to *Acacia modesta*, 1% *Zizyphus spp*. and 7% belong to other species. The average stocking/density was estimated at 362 trees per ha having DBH more than 5 cm. The highest tree stocking was recorded in Parerah Reserved Forests i.e. 676 tree/ha followed by Ara Reserved forests as 292 and Diljabba Reserved Forests as 278 trees per ha.

The results of the inventory show that the forests of the landscape are generally in pole stage. Average tree diameter at breast height was recorded as 10.30 cm and

average height was found as 4.07 m. There was no significant difference in different forest areas in terms of tree size. However, there were significant different between Parerah Forest and other forest areas in terms of canopy cover. Parerah forest has 64% canopy cover whereas Diljabba and Ara Forests have 30% and 37% canopy cover respectively.

The above ground carbon stock in the scrub forests was estimated at 8.20 t/ha. The highest carbon stock was found in Parerah Forests i.e. 11.08 t/ha. Ara and Diljabba Forests have same aboveground carbon stocks i.e. 6.76 t/ha. Mean belowground biomass was estimated at 4.59 t/ha. The total below ground carbon was estimated at 32,888 tonnes.

It was found that litter is not a significant pool of carbon in the scrub forests of Punjab. The total carbon stock in the litter pool was estimated at 3,889 tons with mean of 0.49 t/ha. Highest litter carbon was found in Parera reserved forests 0.83 t/ha followed by Diljabba Forests 0.48 t/ha and Ara Forests 0.40 t/ha. Mean soil organic carbon was found as 37.70 t/ha in area. Highest soil organic carbon was found in Parerah (40.20 t/ha) followed by Ara forest (38.26 t/ha) and Diljabba Forest (35.24 t/ha).Total soil organic carbon the forest area was estimated at 296,339 tons.

The total carbon stock in the scrub forest landscape was estimated at 391,896 tonnes. Out of this 76% is in the soil, 15 % in aboveground biomass, 8% in belowground biomass and 1% in litter. Dead wood is not a significant pool of carbon in the scrub landscape.

Scrub forests have low carbon sequestration potential due to their slow growing nature. It was estimated that these forests can sequester 3.24 tCO_2/ha/year. According to IPCC (2006), subtropical dry forests can sequestration 4-16 tCO_2/ha/year. The scrub forests of Chakwal are currently facing severe pressure of livestock grazing and fuelwood collection due to which carbon stock level is low. However, these forest have enormous potential for biodiversity conservation, soil erosion control and fodder production. Carbon sequestration potential of these forests can be enhanced by afforestation and reforestation using dry zone afforestation techniques and assisted natural regeneration.

1. INTRODUCTION

Forests provide a wide range of ecosystem services which are crucial for sustaining life on this planet and supporting livelihoods of millions of people in the world. Forests help stabilize the climate. They regulate ecosystems, protect biodiversity, play an integral part in the carbon cycle, support livelihoods, and can help drive sustainable growth. The importance of forests has increased many folds in view of their crucial role in climate change mitigation. Forests have four major roles in climate change: they currently contribute about one-sixth of global carbon emissions when cleared, overused or degraded; they react sensitively to a changing climate; when managed sustainably, they produce wood-fuels as a benign alternative to fossil fuels; and finally, they have the potential to absorb about one-tenth of global carbon emissions projected for the first half of this century into their biomass, soils and products and store them for longer time (FAO, 2018).

The crucial role of forests in climate change mitigation and adaptation is now widely acknowledged. Forests contribute significantly to climate change mitigation through their carbon sink and carbon storage functions. They play an important role in reducing climate related risks and vulnerabilities and enhancing adaptation of people and ecosystems to climate change and other natural disasters. The role of forests in climate change mitigation has become a key focus of the international agreements on climate change.

Reducing emissions from deforestation, forest degradation, sustainable forest management, conservation and enhancement of forest carbon stocks known as REDD+ has emerged as a promising option for forest-based climate change mitigation in developing countries. Under the REDD+ programme, developed countries will provide incentives to the developing countries to keep their forests standing and thus help in reducing GHG emissions. One of the key requirements for carbon based forest management is measurement, reporting and verification (MRV) of carbon stocks in the forests (UNFCCC, 2010).

Pakistan is a forest deficient country with only 5% forest cover. Out of its 87.98 million hectare area only 4.51 m ha is under forest cover. Punjab is a low forest cover province of Pakistan with only 553,862 ha (2.7%) forest cover out of which 345,374 ha comprise subtropical broad-leaved forests or scrub forests (Bukhari et al., 2012).

Scrub Forests of Salt Range, Chakwal

Subtropical broad-leaved forests of Salt Range, District Chakwal is one of the two landscapes selected by Sustainable Forest Management Project in Punjab province. The landscape is situated at altitudinal range of 250 m to 1,520 m msl in the outer foothills of the Himalayas. Widely occurring scrub forests, wetlands, world fame Khewra Salt Mine and coal mines, historic forts and Hindu temples are the main characteristic and attractions of Salt Range. Administratively, most of the forests in the landscape fall in the districts of Jhelum and Chakwal.

The climate of valley is characterized by a relatively low annual precipitation (500mm or 20 inches) and average minimum temperature is 1°C in January while average maximum temperature is 36°C in June. Hot dry winds and prolonged period of drought are frequent during summer and winters are accompanied by frost. Little is reported in the related literature about geological history of the Salt Range vegetation while fossil records indicate that the angiosperms date back to the tertiary period while pre-tertiary fossils have no angiosperm affinities (Hussain, 2002). The soil of the area have developed from wind and water-transported material consisting of loess, old alluvial deposits, mountain outwash and recent stream valley deposits; some are derived from shales and sandstones.

The landscape comprises of sub-tropical broadleaved evergreen thorn (scrub) forests. The total area of the landscape under forest is 20,000 ha, out of which 7,859 ha is forested and owned by the state, and 6,672 ha in the outer landscape is private land, including cultivation (1,752 ha) and pastures and settlements 5,469 ha over communal lands. The forest area is state owned comprising of Diljabba Reserved Forest (2,280 ha), Parerah Reserve Forest (1,309 ha) and Ara Reserve Forest (4,270ha).

Generally, the vegetation comprises of thorny and branchy trees with different densities ranging from complete crown cover at favorable sites to scattered single trees or groups on the dry sites, accompanied with considerable coverage with shrubs and grasses. The density of vegetation on southern aspects is poor while on the northern slopes comparatively better. These forests are characterized by conspicuous erosion, gullies and deep ravines. Weathering of sandstone has created small areas of infertile soils which support only limited vegetation. Due to increased biotic pressure, especially grazing and removal of firewood, the remaining vegetation is under severe stress. As a result of severe habitat losses, the depletion of physical and biological resources has become pronounced. Currently, the forest cover is confined to state owned forests in the Salt Range.

Trees species include *Acacia modesta, Olea ferruginea syn cuspidata, Capparis aphylla, Butea frondosa, Tecoma spp., Pistacia integerima, Prosopis glandulosa, Morus alba, ficus bengalensis, dalbergia sissoo; and s*hrub species are *Calatropis procera, Adhatoda vesica, Nerium oleander,Withiana spp. Zizyphus nummularia, Dodonea sissoo, Gymnosporea royaleana*.

The current study was conducted to assess carbon stocks in the landscape and establish baseline of carbon stocks in different pools of the ecosystem.

2. Methodology

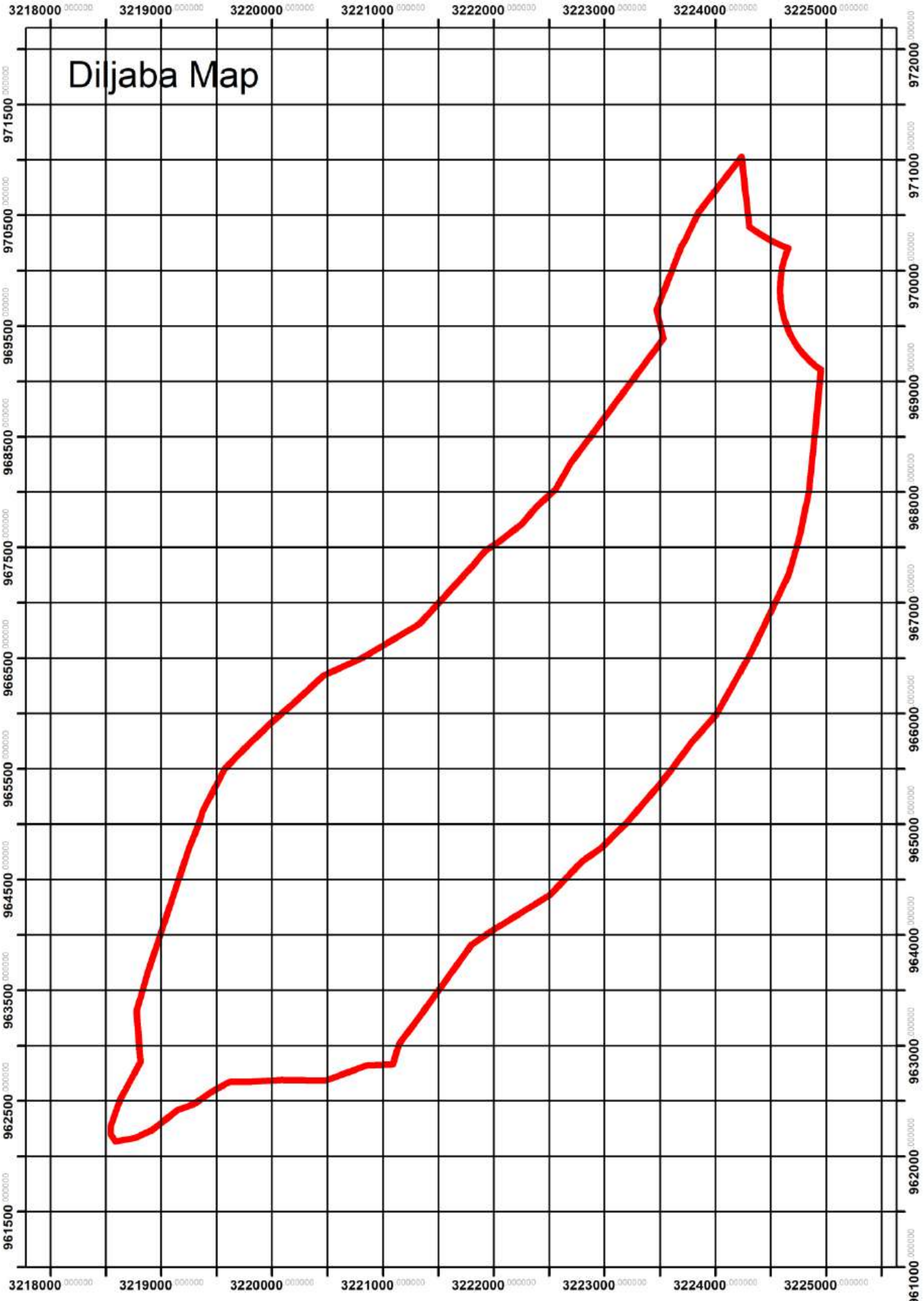
2.1 Forest Carbon Inventory

Carbon stock assessment in the scrub forests of the landscape including Ara Reserved Forests, Diljabba Reserved Forests and Parerah Reserved Forest was conducted during 2018. Two inventory teams were constituted for the field inventory comprising a forestry graduate as a team leader, two Foresters/Forest Surveyor, a driver and a helper. These teams jointly comprised staff of PFI and Punjab Forest Department. Before start of the field work, the teams were properly trained for the field work and acquainted with the inventory design.

GIS maps of scrub forests prepared by GIS Laboratory of Punjab Forest Department were used for locating sample plots. The inventory methodology consists of the following key elements.

2.2 Inventory Design

Systematic random sampling technique was used for collecting data in the field. This sampling design is efficient in reducing the possibility of bias, determining a valid sampling error and ensuring uniform coverage of the target area. Sample plots were laid out on geo-referenced maps of forests using a grid of 500x500 m. The coordinates of the centers of the sample plots were noted from the maps and uploaded onto GPS and navigated in the field accordingly. Beside forest compartment maps, GT sheets were also used to locate the actual position of the sampling units in the field. The plots were permanently marked on the ground by inserting iron rods in the centre of the sample plots for verification and future monitoring.


Diljaba Map
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2.3 Field Measurements

As the current inventory is aimed at estimating biomass and carbon stock in different carbon pools of scrub forests, nested circular plot approach was applied for collecting the data. Circular plot shape was chosen for the inventory due to its easiness in establishment particularly in sloping terrains and to reduce the problem of edge effect associated with rectangular plots. As illustrated in the Figure 1, 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 wider circular plot can be easily and accurately established with the help of Haglöf Vertex. Two options are available in Haglöf Vertex VL5 for measurement of distance i.e. laser and ultrasonic. However, if Haglöfs Vertex was not available, then ordinary measuring tape was used to lay out the sample plot.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.

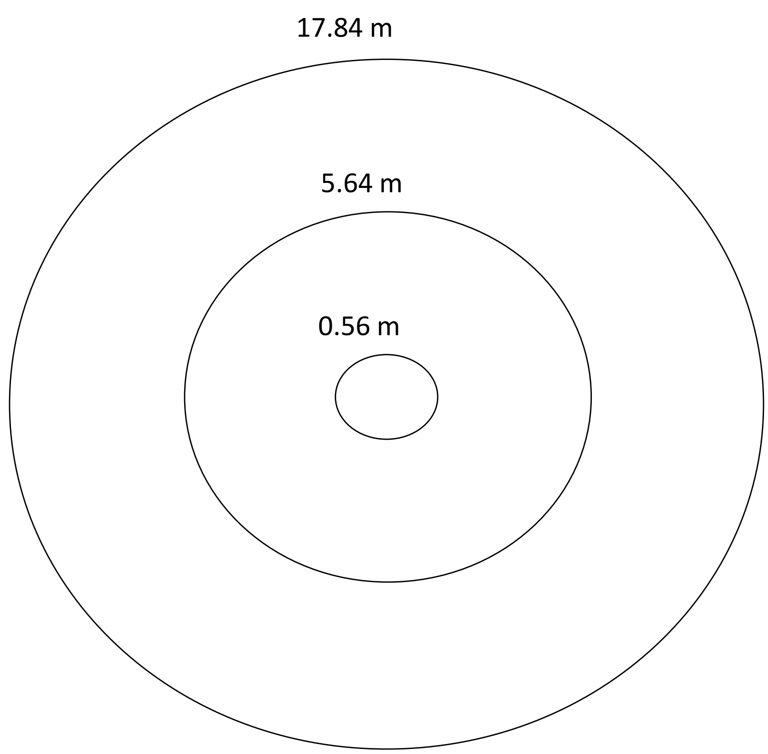

Figure 1. Nested Circular Plot

2.3.1 Above-ground Tree Biomass (AGTB)

Above-ground biomass (AGB) consists of all living vegetation, both woody and herbaceous, above the soil surface including stems, stumps, bark, twigs, seeds and foliage (IPCC, 2006). AGB is divided into two categories, upper story and under story. The wider circular plot of 17.84 m radius (0.1 ha) was used for measuring the attributes of all trees with Diameter at Breast Height (DBH) ≥ 5cm. The plots were laid out with the help of Laser Based Vertix Hypsometer (VL5) which automatically corrects slope of the radius. DBH was measured with dia tape at 1.37 m above ground on uphill side. Heights of randomly selected trees in this circular plot were recorded through Vertix Hypsometer. AGTB was calculated through locally developed allometric equations for major tree species. However for minor tree species the equations available in literature (e.g. Chave et al., 2005) were used.

2.3.2 Above-ground shrub Biomass (AGSB)

Second circular plot with radius 5.64 m (100 m^2 area) was used for measuring biomass of shrubs and saplings. All shrubs of the plot were cut and weighed on the spot. Representative samples were collected, put in bags and their fresh weight was recorded. The samples were taken to PFI for further analysis in the Lab. The samples were dried in the oven at 105^oC till constant weight using a digital balance. Moisture content was determined by the following formula:

MC%=(Fresh Wt of sample – Dry Weight of sample)/Fresh weight of sample x100

2.3.3 Leaf litter, herbs and grasses (LHG)

Third circular plot with radius 0.56 m (1 m^2 area) was used for measuring all leaf, litter, herbs and grasses which were destructively sampled. The material was weighed on the spot and a well-mixed subsample of 100 g was collected for drying in the oven to determine the ratio of ovendry to fresh biomass.

2.3.4 Below-ground Biomass (BGM)

This pool consists of living roots. Fine roots of diameter less than 2 mm are excluded due to the difficulty of separating them from soil organic matter (IPCC, 2006). This is the most difficult pool of forest ecosystem to measure accurately. BGB can be estimated by digging out soil cores, extracting and weighing roots, and drying in the oven. Then the carbon content of the roots is estimated. Due to the difficultly of digging and extracting roots, carbon accounting generally depends on regression equations developed through destructive sampling. These equations predict root biomass on the basis of above-ground biomass (Brown, 2002).

Carbon in the belowground biomass in scrub forests of the landscape was estimated using roo-shoot ratio of 56% as suggested by IPCC for Subtropical Dry Forests (IPCC, 2006). In all pools biomass was converted to carbon stock by multiplying with 0.47 as suggested by IPCC (IPCC, 2006).

2.3.5 Dead Wood

This pool consists of all dead wood including standing and fallen dead trees, stumps and roots with diameter more than 10cm. This pool usually contains carbon in the range of 10-20% of the above-ground pool in mature stands (Delaney *et al*., 1998). However, in young forests and plantations this pool is usually insignificant and therefore ignored in field measurements.

Different methods are applied to estimate carbon in the dead wood pool. Dead standing trees are measured like living trees but their biomass is reduced by 20% for loss of branches and by 2-3% for loss of foliage (McDicken, 1997), that is, their biomass is considered to be 77-78% of that for living trees.

2.3.6 Soil Organic Carbon

Soil organic carbon is an important pool of carbon in the forest ecosystem. This pool is also affected by landuse change and management activities. For measuring soil carbon, samples were collected from 0-15 cm and 16-30 cm for determining bulk density and soil carbon concentration (Subedi et al., 2010). Bulk density was determined on the spot through sample corer and recording fresh weight of the sample. The samples were oven dried in the laboratory at 105C^{o} till constant weight. Subsamples of 50 g were taken for soil carbon determination. The soil carbon was determined through Loss on Ignition (LoI) method using a muffle furnace in the laboratory (Schumacher, 2002; Rehman et al., 2011). Soil organic carbon was calculated by the equation given by IPCC (2003) as follows:

$$SOC = \rho * d * C * 10$$

Where ρ is the bulk density of the soil; d is depth of soil sample; and C is carbon content in the sample.

2.4 General Parameters Recorded

The following parameters were measured at each sample plot location:

- Date
- Name of Data Recorder
- Plot No.
- Location: Name of District, Forest Division, Forest Subdivision/Forest Range, Forest Block, Forest Compartment and Forest Area
- Landuse Class: Forest Land, Grass Land, Crop Land, Wetland, Settlement, Other Land
- Forest Type: Natural Forest, Plantation
- Stand Composition
- GPS Coordinates
- Elevation
- Crown cover

2.5 Sample Size

The total number of sample plots was determined through the following formula:

$$N = \frac{(CV)^2 x t^2}{E^2}$$

Where

N= Number of required sample plots

CV= Coefficient of Variation

t= Student t-test value (1.96 at 95% Confidence Level)

E= Allowable Error

CV was determined through a pilot survey wherein data was collected from 30 sample plots in different forest areas. It was found that CV is 80. The number of the required sample plots was calculated as follows:

$$N = \frac{(80)^2 x 1.96^2}{10^2} = 245$$

Thus it was estimated that 245 sample plots will be sufficient for the given sampling precision.

2.6 Distribution of Sample Plots in different forests

Data was collected from 255 sample plots laid out in scrub forests of Chakwal. The distribution sample plots in different forest areas is given in Table 1.

Table 1: Distribution of Sample Pots in different Forest strata

Forest Area	Forest Area (ha)	Number of Sample Plots
Diljabba Reserved Forest	2,280	70
Ara Reserved Forest	4,270	140
Parerah Reserved Forest	1,309	45
Total	**7,859**	**255**

3. Results

3.1 Growing Stock Composition

Olea ferruginea and *Acacia modesta* are the dominant tree species in the landscape. About 63% of the total trees belong to *Olea ferruginea*, 29% belong to *Acacia modesta*, 1% *Zizyphus spp*. and 7% belong to other species (Figure 2).

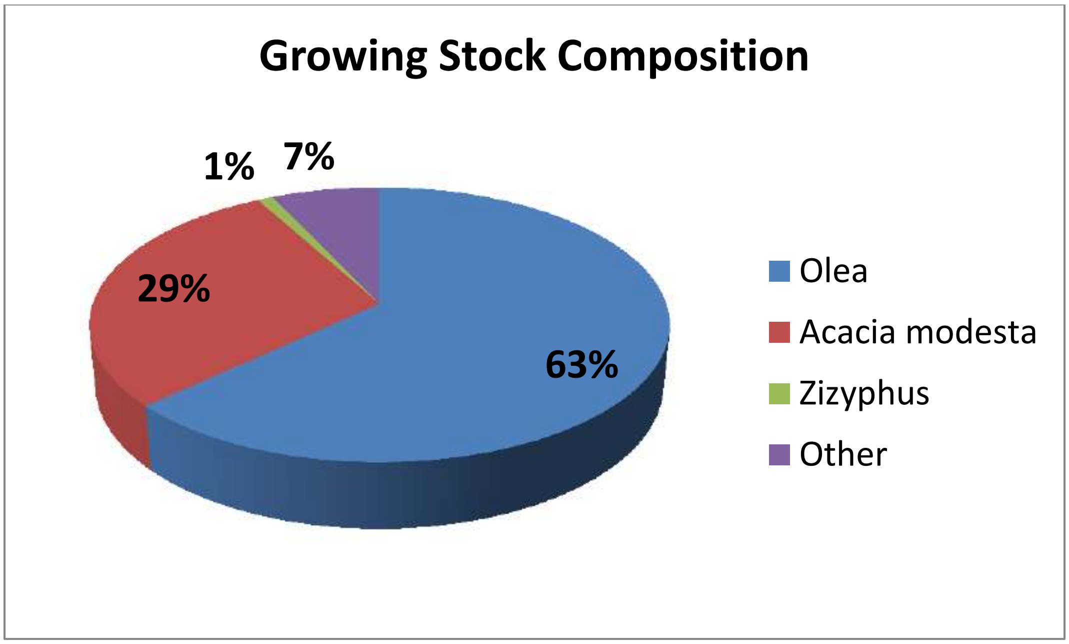

Figure 2: Growing Stock Composition by number of trees

3.2 Growing Stock Composition in Parerah Forest

In Parera, *Olea ferruginea* is the dominant species with 90% share in the total growing stock followed by *Acacia modesta* 5%, *Zizyphus* 1% and other species 4%. Other species included Peelu, Dhaman, Saggar, Shisham, Kari, Semal, Janadar and Janandar.

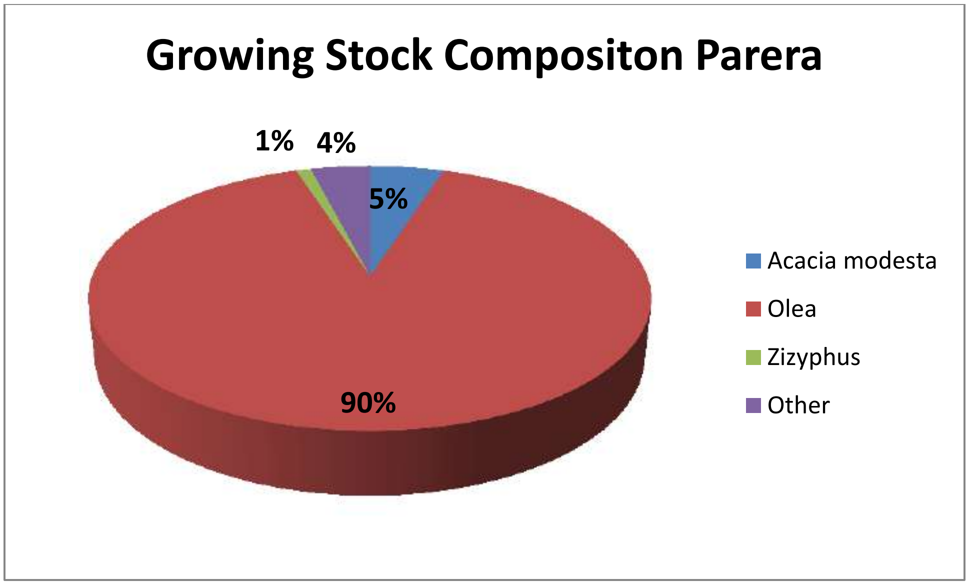

Figure 3: Growing Stock Composition in Parera Forest

3.3 Growing Stock Composition in Diljabba Forest

In Diljabba, *Olea ferruginea* is the dominant species (76%) followed by *Acacia modesta* (18%), *Zizyphus* 1% and other species 5%. Other species include Garanda, Saggar, Kandir, Dhaman, Kawi and Farash.

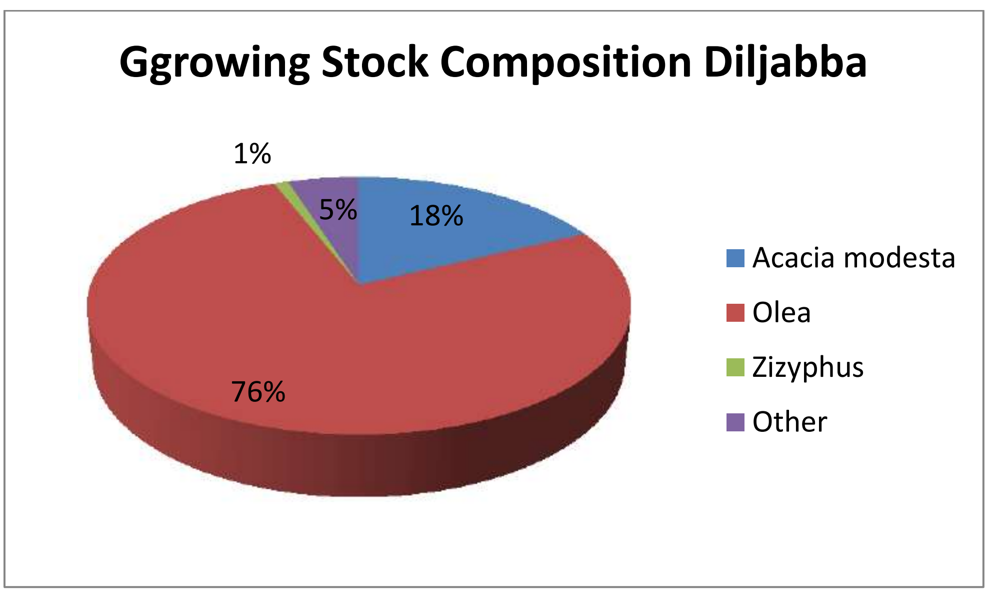

Figure 4: Growing Stock Composition in Diljabba Fforest

3.4 Growing Stock Composition in Ara Forest

In Ara forest, *Acacia modesta* is the domant species (53%), followed by *Olea ferruginea* (34%), *Zizyphus* (2%) and others (11%). Other species included Dhaman, Saggar, Baikar, Semal, Wand, Kari, Peelu and Meri.

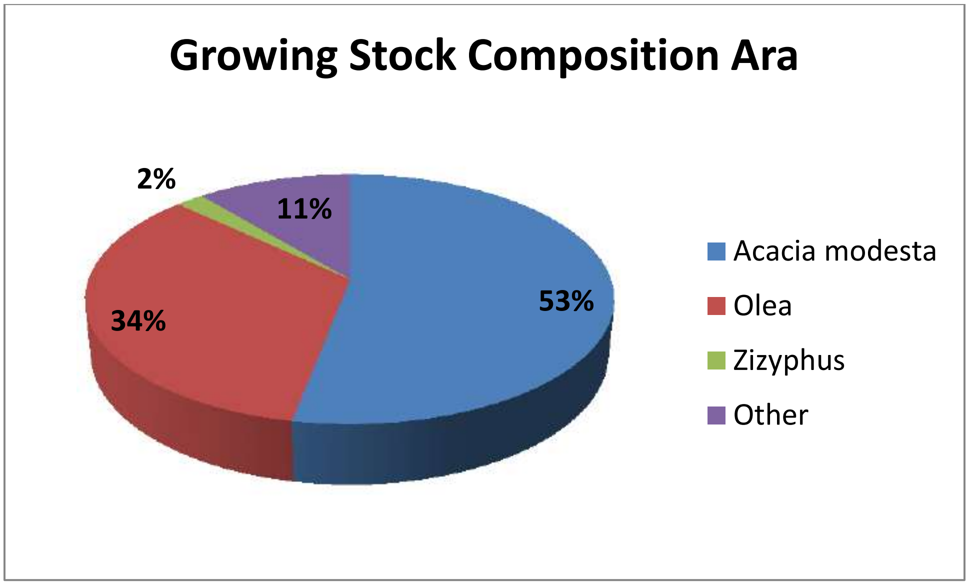

Figure 5: Growing Stock Composition in Ara Forest

3.5 Tree Stocking/Density

The average stocking/density was estimated at 362 trees per ha having DBH more than 5 cm. The highest tree stocking was recorded in Parerah Reserved Forests i.e. 676 tree/ha followed by Ara Reserved forests as 292 and Diljabba Reserved Forests as 278 trees per ha (Table 2).

Table 2: Tree Stocking/Density

Forest Area	**Number of Trees/ha**
Diljabba Reserved Forest	278
Ara Reserved Forest	292
Parerah Reserved Forest	676
Total	**362**

3.6 Stand Structure

The results of the inventory show that the forests of the landscape are generally in pole stage. Average tree diameter at breast height was recorded as 10.30 cm and average height was found as 4.07 m. There was no significant difference in different forest areas in terms of tree size. However, there were significant different between Parerah Forest and other forest areas in terms of canopy cover. Parerah forest has 64% canopy cover whereas Diljabba and Ara Forests have 30% and 37% canopy cover respectively (Table 3).

Table 3: Stand Structure

Forest Area	Mean DBH (cm)	Mean Height (m)	Av. Canopy Cover (%)
Diljabba Reserved Forest	10.28	3.90	30
Ara Reserved Forest	11.17	4.27	37
Parerah Reserved Forest	9.46	4.06	64
Total	**10.30**	**4.07**	**44**

3.7 Aboveground Carbon Stock

Aboveground biomass in the landscape comprises trees and shrubs. The above ground carbon stock in the scrub forests was estimated at 8.20 t/ha. The highest carbon stock was found in Parerah Forests i.e. 11.08 t/ha. Ara and Diljabba Forests have same aboveground carbon stocks i.e. 6.76 t/ha (Table 4).

Table 4: Aboveground carbon stocks in different forest areas

Forest Area	Forest Area	Aboveground C stock (t/ha)	Aboveground C stock (ton)
Diljabba Reserved Forest	2,280	6.76	15,413
Ara Reserved Forest	4,270	6.76	28,865
Parerah Reserved Forest	1,309	11.08	14,504
Total	**7,859**	**8.20**	**58,782**

3.8 Belowground Biomass

Carbon in the belowground biomass in scrub forests of the landscape was estimated using roo-shoot ratio of 56% as suggested by IPCC for Subtropical Dry Forests (IPCC, 2006). Mean belowground biomass was estimated at 4.59 t/ha. The total below ground carbon was estimated at 32,888 tonnes. Detail of carbon stock in belowground biomass in different forest areas is given in the Table 5.

Table 5: Below-ground carbon stocks in different forest areas

Forest Area	Area (ha)	Belowground C stock (t/ha)	Belowground C stock (tons)
Diljabba Reserved Forest	2,280	3.78	8,618
Ara Reserved Forest	4,270	3.78	16,140
Parerah Reserved Forest	1,309	6.21	8,129
Total	**7,859**	**4.59**	**32,888**

3.9 Litter Carbon

It was found that litter is not a significant pool of carbon in the scrub forests of Punjab. The total carbon stock in the litter pool was estimated at 3,889 tons with mean of 0.49 t/ha. Highest litter carbon was found in Parera reserved forests 0.83 t/ha followed by Diljabba Forests 0.48 t/ha and Ara Forests 0.40 t/ha (Table 6). More litter in Parerah forests was due to high density of aboveground vegetation in the area as compared to other forest areas.

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

Forest Area	Area (ha)	Litter C stock (t/ha)	Litter C stock (tons)
Diljabba Reserved Forest	2,280	0.48	1,094
Ara Reserved Forest	4,270	0.40	1,708
Parerah Reserved Forest	1,309	0.83	1,086
Total	**7,859**	**0.49**	**3,889**

3.10 Soil Organic Carbon

Soil samples were collected from 30 cm depth. Mean soil organic carbon was found as 37.70 t/ha in area. Highest soil organic carbon was found in Parerah (40.20 t/ha) followed by Ara forest (38.26 t/ha) and Diljabba Forest (35.24 t/ha). Total soil organic carbon the forest area was estimated at 296,339 tons (Table 7).

Table 7: Soil organic carbon in different forest areas

Forest Area	Area (ha)	Soil Organic Carbon (t/ha)	Soil carbon (tons)
Diljabba Reserved Forest	2,280	35.24	80,347
Ara Reserved Forest	4,270	38.26	163,370
Parerah Reserved Forest	1,309	40.20	52,622
Total	**7,859**	**37.70**	**296,339**

3.11 Total carbon stock in the Landscape

The total carbon stock in the scrub forest landscape was estimated at 391,896 tonnes. Out of this 76% is in the soil, 15 % in aboveground biomass, 8% in belowground biomass and 1% in litter (Figure 6). Dead wood is not a significant pool of carbon in the scrub landscape. Distribution of carbon stocks in various pools in different forest areas is given in Table 8.

Table 8: Distribution of carbon stocks in different pools and forest areas

Forest Area	AGC (tons)	BGC (tons)	Litter C (tons)	SOC (tons)	Total C (tons)	C Density (t/ha)
Diljabba Reserved Forest	15,413	8,618	1,094	80,347	105,472	46.26
Ara Reserved Forest	28,865	16,140	1,708	163,370	210,083	49.20
Parerah Reserved Forest	14,504	8,129	1,086	52,622	76,341	58.32
Total	**58,782**	**32,888**	**3,889**	**296,339**	**391,896**	**49.87**

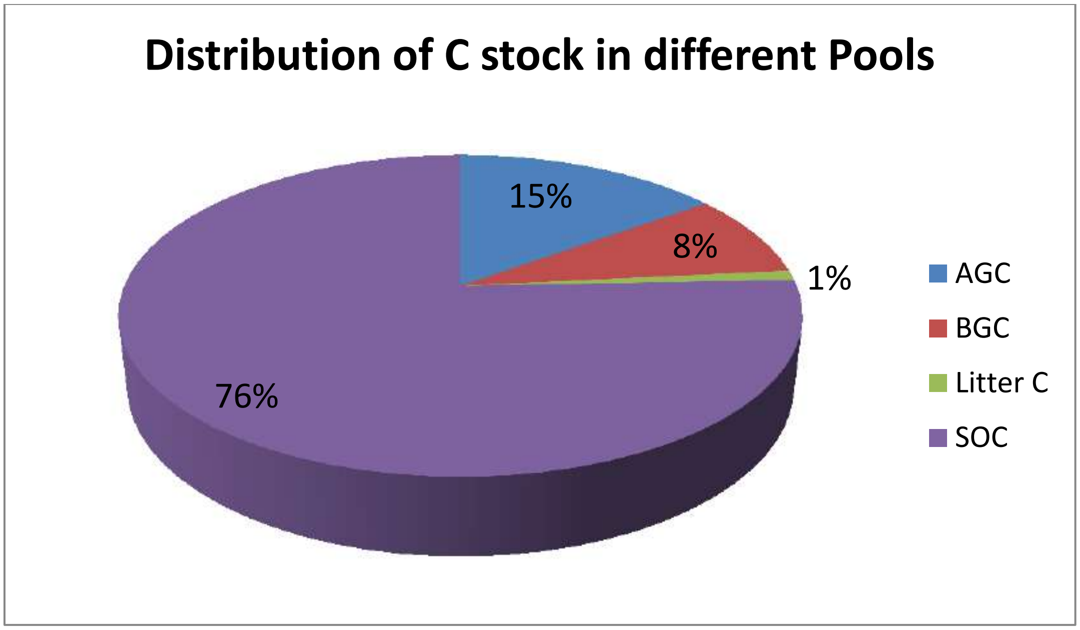

Figure 6: Distribution of carbon stocks in different pools

3.12 Carbon sequestration Potential

Scrub forests have low carbon sequestration potential due to their slow growing nature. It was estimated that these forests can sequester 3.24 tCO_2/ha/year. According to IPCC (2006), subtropical dry forests can sequestration 4-16 tCO_2/ha/year. The scrub forests of Chakwal are currently facing severe pressure of livestock grazing and fuelwood collection due to which carbon stock level is low. However, these forests have enormous potential for biodiversity conservation, soil erosion control and fodder production. Carbon sequestration potential of these forests can be enhanced by afforestation and reforestation using dry zone afforestation techniques and assisted natural regeneration.

Carbon stock assessment in scrub forest of Samarkand, District Chakwal in collaboration with Punjab Forest Department

1. Samarkand Forest

Samarkand is the newly selected site under SFM Project in Punjab. It contains subtropical broad-leaved forests commonly called as Scrub forest and typically representing the natural vegetation of Salt Range. Samarkand is part of Chakwal Forest Division. It has two blocks i.e. Samarkand North and Samarkand South. The total area of the landscape is 5,540 ha. Samarkand North has an area of 2,117 ha and Samarkand South has an area of 3,422 ha.

Generally, the vegetation comprises of thorny and branchy trees with different densities ranging from complete crown cover at favorable sites to scattered single trees or groups on the dry sites, accompanied with considerable coverage with shrubs and grasses. The density of vegetation on southern aspects is poor while on the northern slopes comparatively better. These forests are characterized by conspicuous erosion, gullies and deep ravines. Weathering of sandstone has created small areas of infertile soils which support only limited vegetation. Due to increased biotic pressure, especially grazing and removal of firewood, the remaining vegetation is under severe stress. As a result of severe habitat losses, the depletion of physical and biological resources has become pronounced. Currently, the forest cover is confined to state owned forests in the Salt Range.

Trees species include *Acacia modesta, Olea ferruginea syn cuspidata, Capparis aphylla, Butea frondosa, Tecoma spp., Pistacia integerima, Prosopis glandulosa, Morus alba, ficus bengalensis, dalbergia sissoo; and s*hrub species are *Calatropis procera, Adhatoda vesica, Nerium oleander,Withiana spp. Zizyphus nummularia, Dodonea sissoo, Gymnosporea royaleana*.

3.2.1 Carbon stock assessment in Samarkand forest

Carbon stock assessment in the scrub forests of Samarkand was conducted during Januar-March 2019. A pre-defined grid of 500x500 m was laid out on the map of each forest and the geographic coordinates of the intersections of the grids were recorded and upload onto GPS devices (Etrix 30). According to this grid there were 220 sampling points falling inside the map of the area (Figure 7). However, some of the sample plots were inaccessible or falling in totally blank areas, therefore, data was collected from 198 sample plots using a systematic random sampling technique. Out of these sample plots, 74 sample plots were located in Samarkand North and 124 were laid out in Samarkand South. The locations of the sample plots are shown in the following Figure 8. The sample plots were navigated with the help of GPS and maps of the forests. When reach at the sample plot location, the centres of the sample plots were determined and marked on the ground for future monitoring and verification. Data was collected on aboveground tree biomass, shrub biomass, litter, dead wood and soil organic carbon using a nested circular plot approach. Below ground biomass was determined using root-shoot ratios from IPCC Guideline 2006.

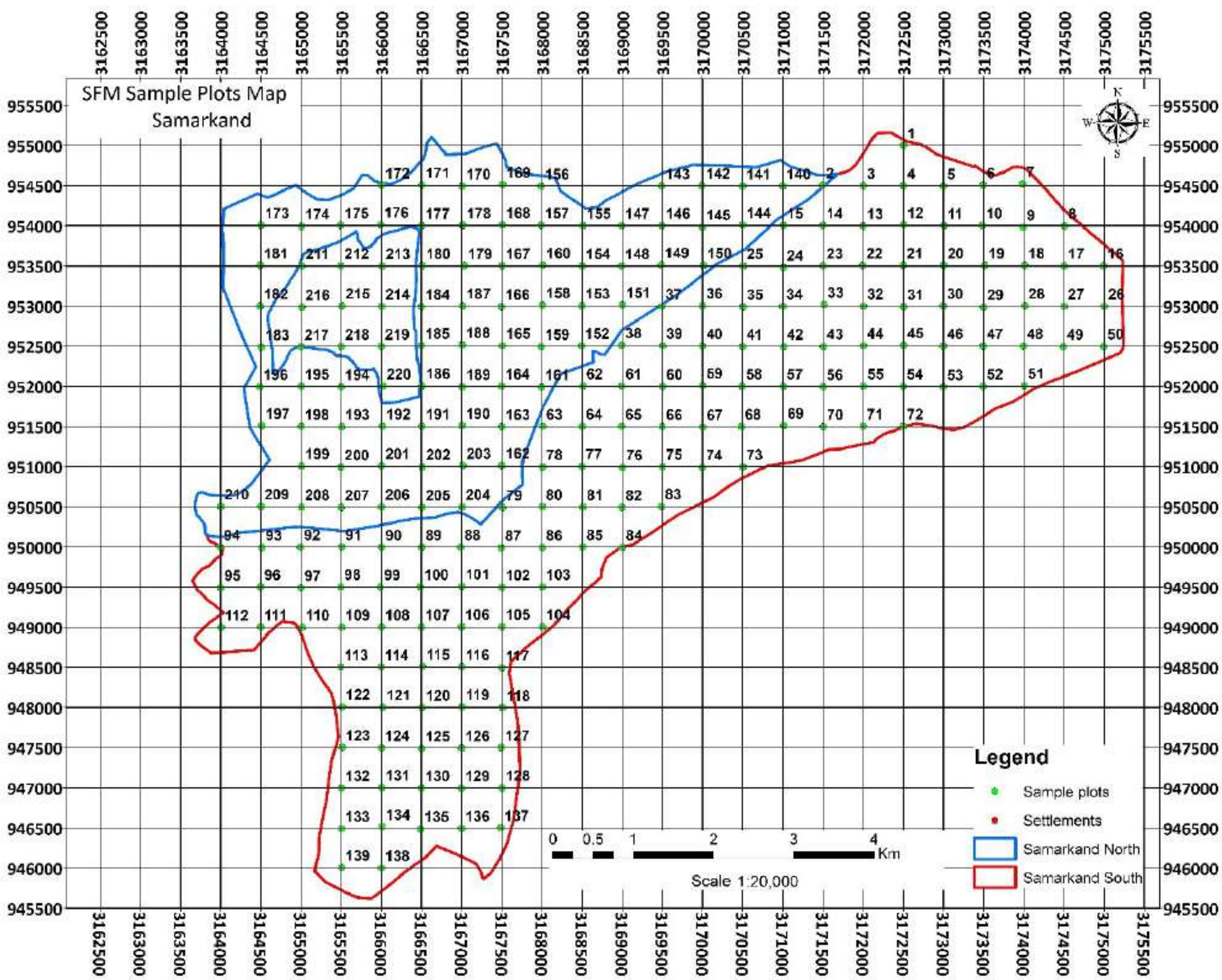

Figure 7: Systematic grid of 500x500 m used for filed sampling

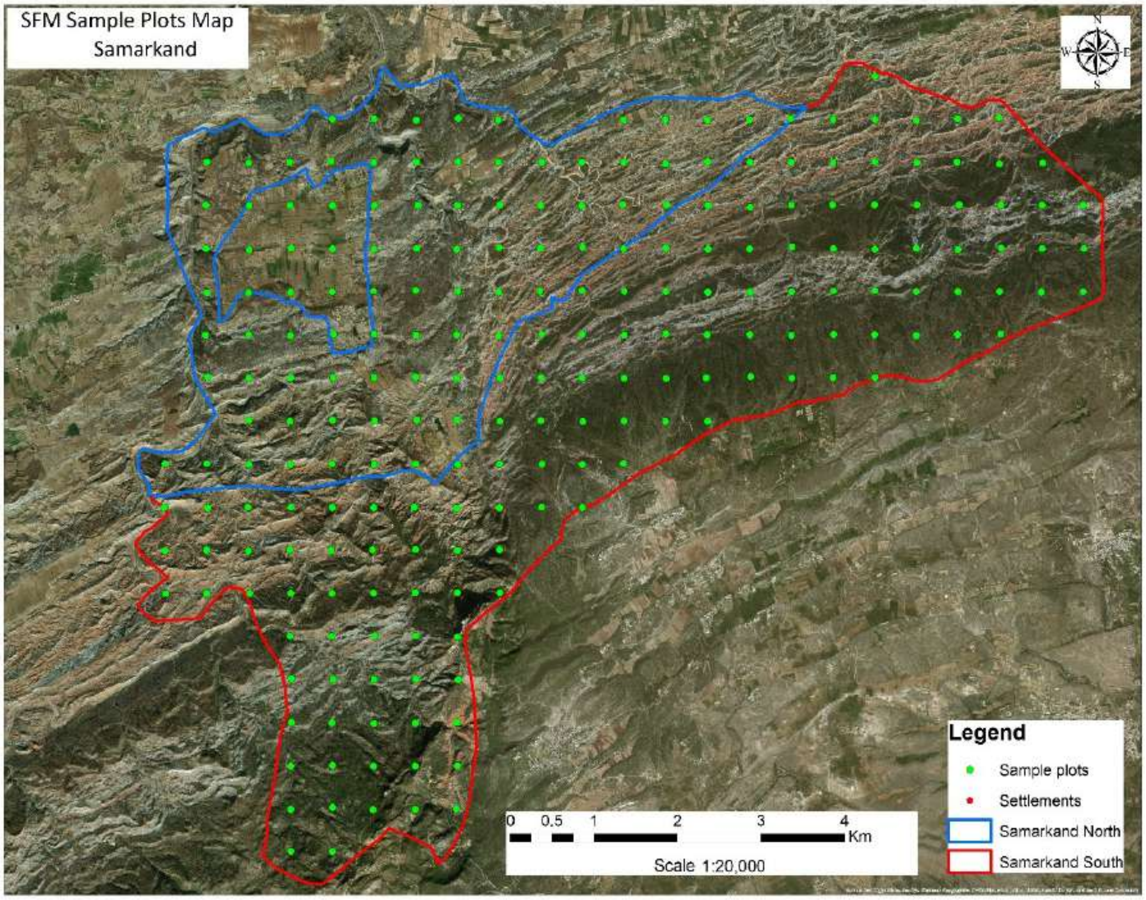

Figure 8: Distribution of sample plots in Samarkand

3.2.2 Growing Stock Composition

Acacia modesta, A. nilotica, Olive, and Zyziphus are the major tree species in the landscape. About 83% of the growing stock comprises *Acacia modesta*, 13% *Olea ferruginea*, 2% *Zizyphus spp*. , 1% *Acacia nilotica* and 2% other species (Figure 9).

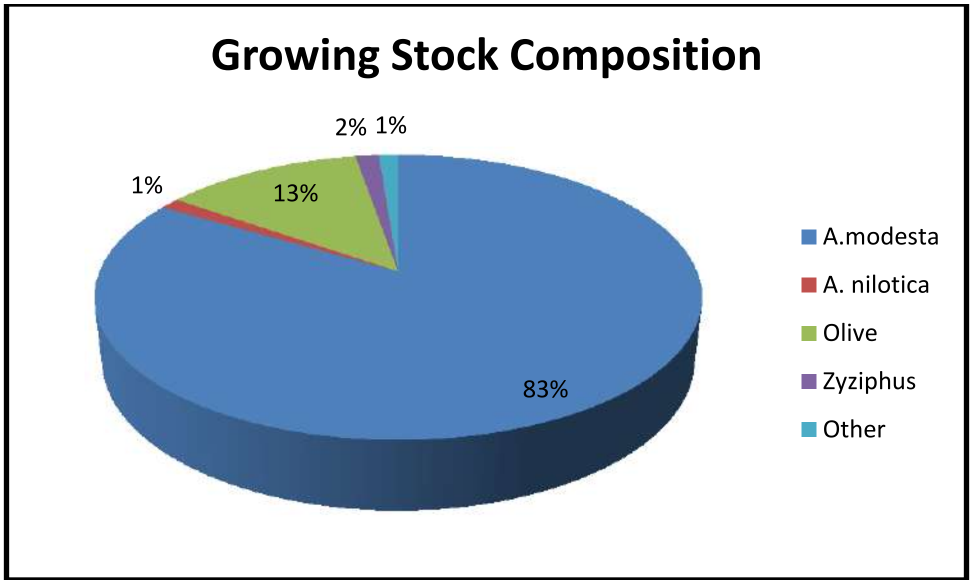

Figure 9: Growing Stock Composition by number of trees

3.2.3 Forest Characteristics

The average stocking/density was estimated at 148 trees/ha in the forest area. In Samarkand North the density was 161 stems/ha and in Samarkand South stocking/density was 142 stems/ha. Mean elevation of the forest area was 634 m above mean sea level. Mean slope of the forest land was estimated at 50% and crown cover was determined as 33%. There were no significant differences between Samarkand North and Samarkand South in terms of mean elevation, mean slope and crown cover. The detail is given in the following table 9.

Table : Forest Characteristics

Forest Area	**Number of Trees/ha**	**Mean Elevation (m)**	**Mean Slope (%)**
Samarkand North	161	572	48
Samarkand South	142	671	50
Total	**148**	**634**	**50**

 

3.2.4 Stand Structure

Like other scrub forests of the Salt Range, the forests of Samarkand are generally in pole stage. Average tree diameter at breast height was recorded as 9.61 cm and average height was found as 5.2 m. Mean DBH in Samarkand North was found 8.71 cm and mean DBH in Samarkand South was estimated at 10.15 cm. There was no significant difference between Samarkand North and Samarkand South in terms of canopy cover.

Table 10: Stand Structure

Forest Area	Mean DBH (cm)	Mean Height (m)	Av. Canopy Cover (%)
Samarkand North	8.71	5.05	32
Samarkand South	10.15	5.28	34
Total	**9.61**	**5.2**	**33**

3.2.5 Aboveground Biomass and Carbon Stock

Aboveground biomass refers to the biomass of trees and shrubs. Mean aboveground biomass in Samarkand forest area was estimated as 7.52 t/ha and mean aboveground carbon stock was determined as 3.53 t/ha. In Samarkand North the aboveground biomass and carbon stock were 4.95 t/ha and 2.33 t/ha respectively. On the other hand, in Samarkand South the aboveground biomass and carbon stock were found as 7.80 t/ha and 3.66 t/ha. Thus, it was found that Samarkand South have high carbon density than Samarkand North due to comparatively better vegetation growth in Samarkand South.

Table 11: Aboveground biomass carbon stock

Forest Area	Area (ha)	Aboveground C stock in Trees (t/ha)	Aboveground C stock in Shrub (t/ha)	Aboveground C stock Trees+ Shrub (t/ha)	Total AGC (Tonnes)
Samarkand North	2,117	2.23	0.43	2.66	5,631
Samarkand South	3,422	3.15	0.76	3.91	13,380
Total	5,540	**2.82**	**0.714**	**3.53**	**19,011**

3.2.6 Belowground Biomass

Carbon in the belowground biomass in scrub forests of Samarkand was estimated using root-shoot ratio of 56% as suggested by IPCC for Subtropical Dry Forests (IPCC, 2006). Mean belowground biomass was estimated at 1.98 t/ha. The total below ground carbon was estimated at 9,767 tonnes in the landscape. Detail of carbon stock in belowground biomass in Samarkand Forest is given in the Table 12.

Table 12: Below-ground carbon stock

Forest Area	**Area (ha)**	**Belowground C stock (t/ha)**	**Belowground C stock (tons)**
Samarkand North	2,117	1.30	2,752
Samarkand South	3,422	2.05	7,015
Total	5,540	1.98	**9,767**

3.2.7 Litter Carbon

Litter is an important pool of carbon in the scrub forests of Samarkand. The total carbon stock in the litter pool was estimated at 5,008 tons with mean of 0.91 t/ha. The litter carbon ranged from 0.26 t/ha to 3.28 t/ha (Table 13). In Samarkand North, the litter carbon was 0.83 t/ha and in Samarkand South it was found as 0.95.

Table 13: Estimates of carbon stocks in litter in different forest areas

Forest Area	**Area (ha)**	**Litter C stock (t/ha)**	**Litter C stock (tons)**
Samarkand North	2,117	0.83	1,757
Samarkand South	3,422	0.95	3,251
Total	5,540	**0.91**	**5,008**

3.2.8 Soil Organic Carbon

Soil organic carbon is an important pool of carbon in the forest ecosystem. Soil samples were collected from 30 cm depth. Soil analysis is in progress in PFI Soil Laboratory. The results of about 10 samples indicate that mean soil organic carbon is 36.40 t/ha in area.

Table 14: Estimates of soil carbon stocks

Forest Area	**Area (ha)**	**SOC (t/ha)**	**SOC (tons)**
Samarkand North	2,117	36.60	77,482
Samarkand South	3,422	36.60	125,245
Total	5,540	36.60	**202,727**

 

3.2.9 Total carbon stock in the Landscape

The total carbon stock in the scrub forest landscape was estimated at **236,513**tonnes. Out of this 86% is in the soil, 8 % in aboveground biomass, 4% in belowground biomass and 2% in litter (Figure 3.10). Dead wood is not a significant pool of carbon in the scrub landscape. Distribution of carbon stocks in various pools in different forest areas is given in Table 7.

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

Forest Area	**AGC (tons)**	**BGC (tons)**	**Litter C (tons)**	**SOC (tons)**	**Total C (tons)**	**C Density (t/ha)**
Samarkand North	5,631	2,752	1,757	77,482	87,622	41.39
Samarkand South	13,380	7,015	3,251	125,245	148,891	43.51
Total	**19,011**	**9,767**	**5,008**	**202,727**	**236,513**	42.70

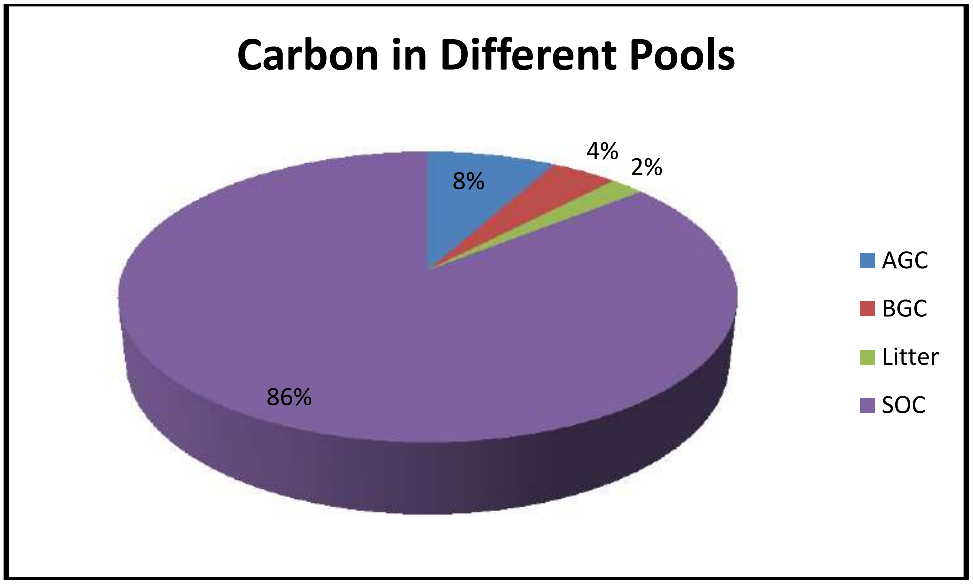

Figure 10: Distribution of carbon stocks in different pools

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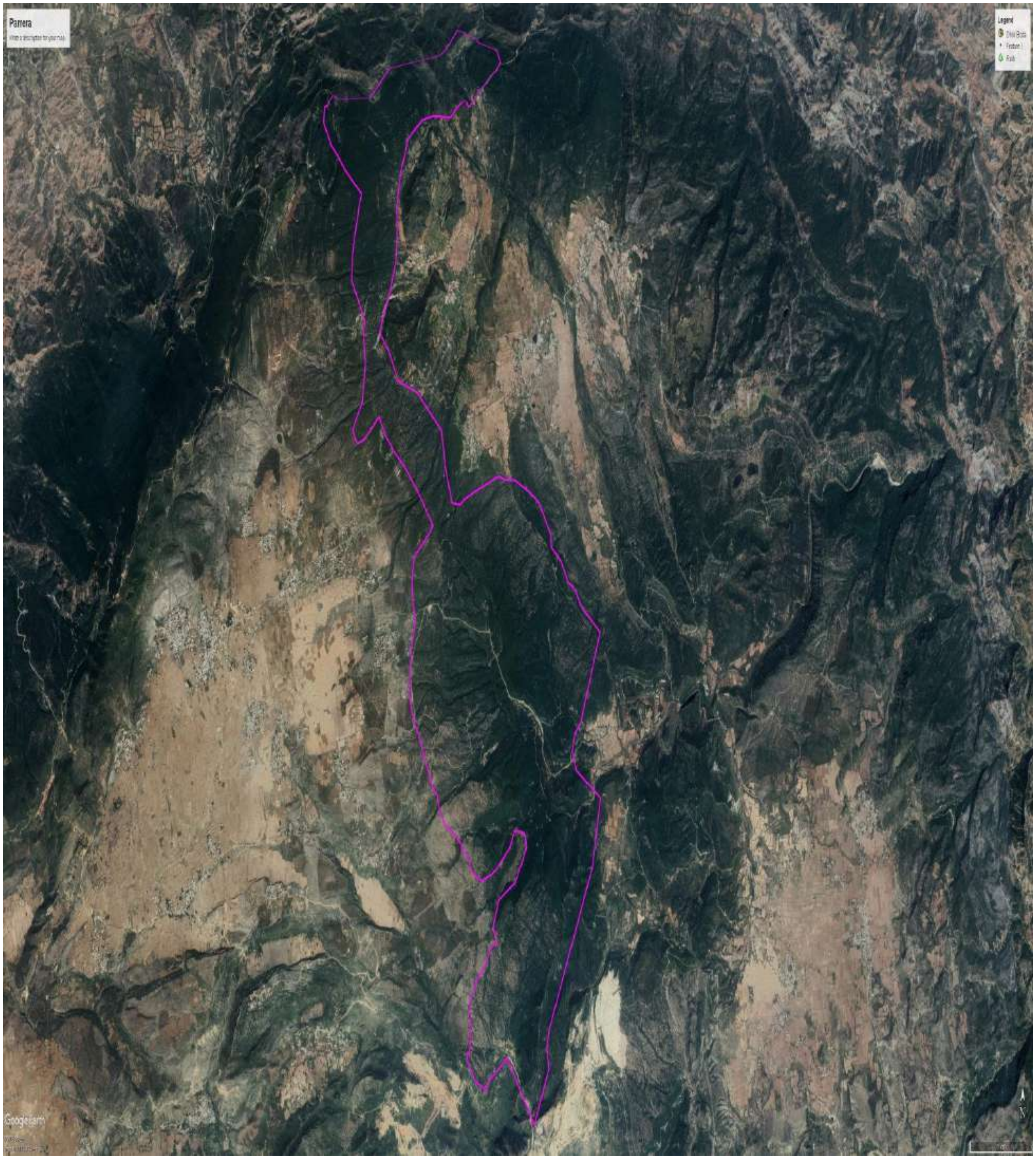
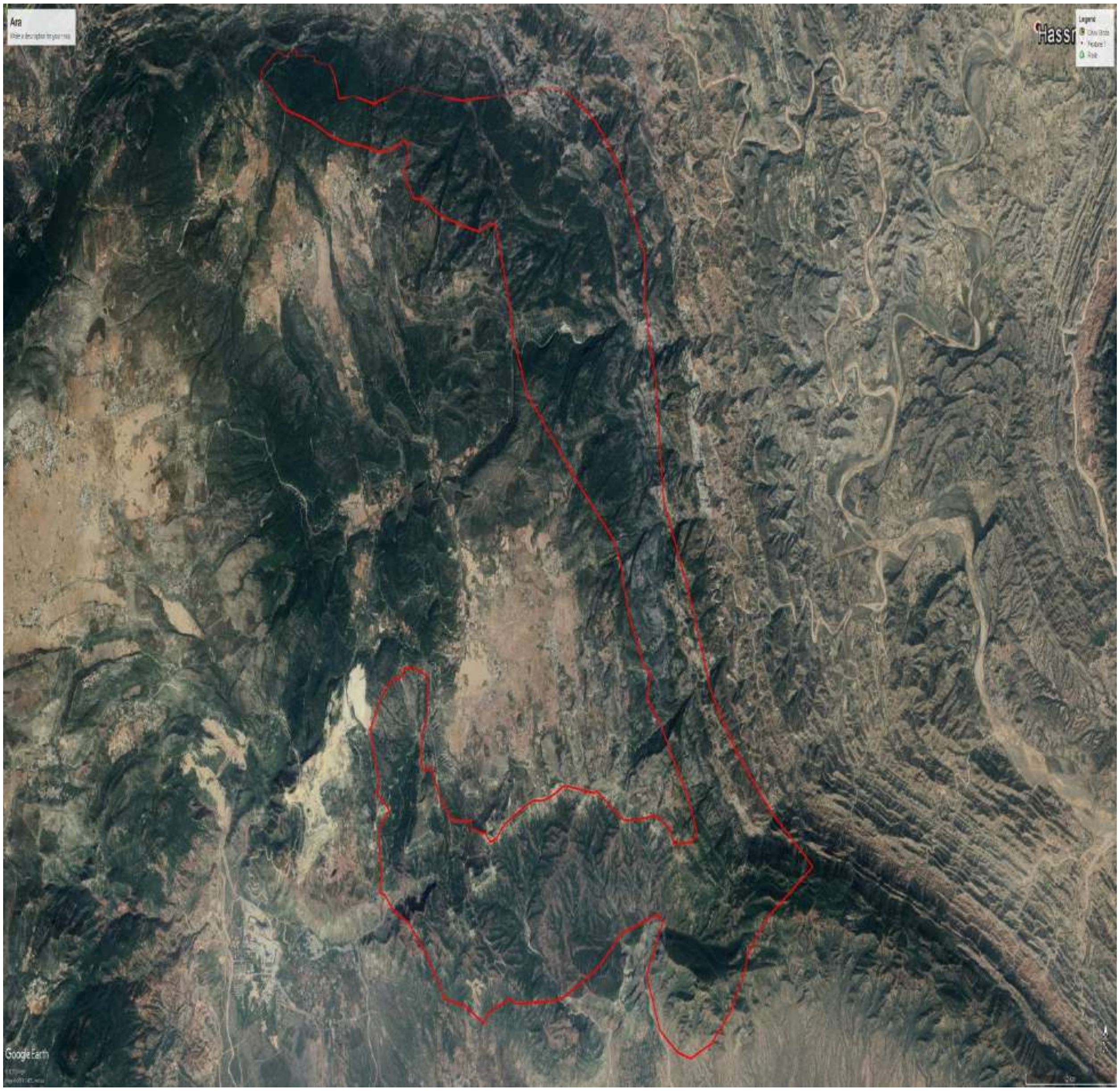
ANNEX-I
Maps of Parera Forest



ANNEX-II
Map of Diljabba Forest

ANNEX-III

Map of Ara Forest



ANNEX-IV
DATA COLLECTION FORM

Dated:____________________ Recorder Name: ______________________________

Plot No. ___________ Location: ________________________ Compartment: _______________

GPS Coordinates: X ___________________ Y ________________Elevation (m)_______________

Aspect_____________ Slope (%):__________ Crown Cover: ________ Forest Type:____________

Tree No.	Species	DBH (cm)	Height (m)	Increment	Tree form	Crown Dia
1.						

Sapling/ Regeneration Biomass Plot radius:______

No.	Spp.	Dia. at base	Ht. (m)	Fresh Wt. (gm)

Shrubs Biomass Plot radius:_________

	Shrub cover (%)			
	Portion of plot cut	Full	½	¼
	Total Wt. (Kg)			
	Sample Wt. (Kg)			

Stumps Biomass

No.	Dia. (cm)	Height (m)	Decay %	

CWD/Dead Wood

No.	Weight	Dia.	Length (m)	

Leaf/litter/Grass Biomass

Total Wt. (Kg)		Sample Wt. (Kg)	

Soil Sample Weight (gm)

0-15 (Cm)		15-30 (Cm)	