Sustainable Forest Management Project

Carbon Stock Assessment in Coniferous Forests of Siran, District Mansehra, Khyber Pakhtunkhwa

By

Anwar Ali

PAKISTAN FOREST INSTITUE, PESHAWAR

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CONTENTS

List of Acronyms and Abbreviations

AGC	Aboveground Carbon
AGTB	Aboveground Tree Biomass
AGM	Aboveground Biomass
asl	Above Sea Level
BGC	Belowground Carbon
BL	Broad-Leaved
cm	Centimeter
C	Carbon
CO_2	Carbon dioxide
CV	Coefficient of Variation
DBH	Diameter at Breast height
DEM	Digital Elevation Model
FSMP	Forestry Sector Master Plan
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
RS	Remote Sensing
SD	Standard Deviation
SE	Standard Error
t	Tonne
UNFCCC	United Nations Framework Convention on Climate Change

SUMMARY

The state forests in the Siran landscape include Panjul Reserved Forest (2,482 ha) and Una Reserve Forest (2,249 ha) and Guzara (community) forests including Deoli Guzara Forest (5,028 ha), Jachha Guzara Forest (1,330 ha) and Manda Guchha Guzara Forest (2,655 ha). The area of two state forests and the three Guzara (communal) forests is 4,731 ha and 9,013 ha respectively, the total area being 13,744 ha. A total of 253 sample plots were laid out in different forests for data collection. Out of it 93 sample plots were laid out in Reserved Forests and 160 were in Guzara forests.

A total of 2,066 trees belonging to 23 different species were tallied during field inventory in Siran. The tree species sampled predominantly consisted of conifers (95%). The remaining 5% trees were broad-leaved trees belonging to 17 different species. The species composition is shown in the Figure 2. Kail (*Pinus wallichiana*) is the dominant species (37%) followed by Spruce (*Picea smithiana*) 29% and Fir (*Abies pindrow*) 25%. Deodar (*Cedrus deodara*) has 3% share in the total trees. In broad-leaved Horse chestnut, oak and walnut are important species.

The average stocking/density was estimated at 109 trees per ha having DBH more than 5 cm. In Reserved Forests, the average number of trees per ha was estimated at 113 whereas in Guzara Forests, the tree density was 106 trees per ha. About 64% of the trees fall in immature class followed by sub-mature with 24% sample trees. Thus about 88% of the trees are young and sub-mature and about 12 % of the sample trees are mature.

The above ground carbon stock in the forests of the SFM Project area in Siran Forest Division, Mansehra was estimated at 445,698 ton. Carbon density 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. The total carbon stock in the SFM Project area of Siran Forest Division was estimated at 1,362,927 tonnes. Out of this 56% is in the soil, 33 % in aboveground biomass, 9% in belowground biomass and 2% in litter.

1. INTRODUCTION

Forests and forestry are gaining central importance at the global stage due to their key role in climate change mitigation. When forests grow, they sequester carbon from the atmosphere and store this carbon in the form of biomass and soil organic carbon. Traditionally forests have been managed for timber production. However, now the ecological functions of forests are getting more importance than their tangible benefits. Carbon forestry is becoming an important discipline of sustainable forest management.

Realizing the importance of forests in climate change mitigation, UNFCCC has devised a mechanism known as REDD+ to encourage and reward developing countries to keep their forests intact 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. It is therefore essential to estimate carbon stocks and changes therein over time to get financial benefit from the international carbon market.

Siran Valley, located in Mansehra District of Khyber Pakhtunkhwa is one of the two sites of moist temperate forests selected by Sustainable Forest Management Project for its interventions. The state forests in the landscape include Panjul Reserved Forest (2,482 ha) and Una Reserve Forest (2,249 ha) and Guzara (community) forests including Deoli Guzara Forest (5,028 ha), Jachha Guzara Forest (1,330 ha) and Manda Guchha Guzara Forest (2,655 ha). The area of two state forests and the three Guzara (communal) forests is 4,731 ha and 9,013 ha respectively, the total area being 13,744 ha.

2. Methodology

Carbon stock assessment in the forests of Siran Valley was conducted during May-November, 2018. Two inventory teams were constituted for the field inventory comprising a forestry graduate as a team leader, two Field Assistants, a driver and a helper. Before start of the field work, the team was properly trained for the field work and acquainted with the inventory design. Forest area is currently being determined and mapped through interpretation of high resolution satellite imageries. However, these estimates are still not available, therefore, the estimates of forest are of different compartments were obtained from Planning and Monitoring Circle of Khyber Pakhtunkhwa Forest Department. These area estimates were used to assess total carbon stock in the project area. Species wise allomteric models have already been developed by Pakistan Forest Institute for the area which were used to derive biomass from the field data. The details of methods employed for field inventory are given in the following sections.

2.1 Forest Carbon Inventory

Before designing the forest inventory, relevant literature and guidelines were collected and extensively reviewed to devise a methodology in conformity with international standards. 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 a geo-referenced map using a grid of 700 x700 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.

2.3 Field Measurements

As the current inventory is aimed at estimating biomass and carbon stock in different carbon pools of a forest ecosystem, nested circular plot approach was applied for collecting the requisite 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 (or 8.92 m in case of dense forest) 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.

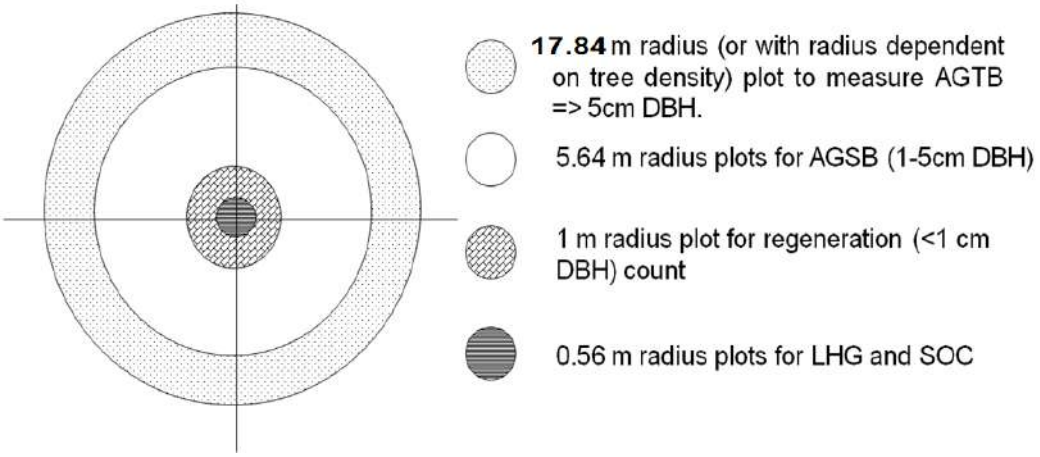

Figure 1. Nested Circular Plot

2.3.1 Above-ground Tree Biomass (AGTB)

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^{o}C till constant weight using a digital balance. Moisture content was determined by the following formula:

MC%=(Fresh Wt of sample – Dry Wieght 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)

BGM was estimated using default values from IPCC Guidelines (2006). In all pools biomass was converted to carbon stock by multiplying with 0.47 as suggested by IPCC (IPCC, 2006).

2.3.5 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.

- Compartment No.
- Stand Composition
- GPS Coordinates
- Elevation
- Slope
- Aspect
- 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

Based on the above formula, data was collected from 253 sample plots laid out uniformly in the entire forest area through a systematic random sampling as described in the previous section.

2.6 Distribution of Sample Plots in different forests

A total of 253 sample plots were laid out in different forests for data collection. Out of it 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 strata

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**




3. Results

3.1 Growing Stock Composition

A total of 2,066 trees belonging to 23 different species were tallied during field inventory. The tree species sampled predominantly consisted of conifers (95%). The remaining 5% trees were broad-leaved trees belonging to 17 different species. The species composition is shown in the Figure 1. Kail (*Pinus wallichiana*) is the dominant species (37%) followed by Spruce (*Picea smithiana*) 29% and Fir (*Abies pindrow*) 25%. Deodar (*Cedrus deodara*) has 3% share in the total trees. In broad-leaved Horse chestnut, oak and walnut are important species. Other species have 2% share in the total growing stock in Siran.

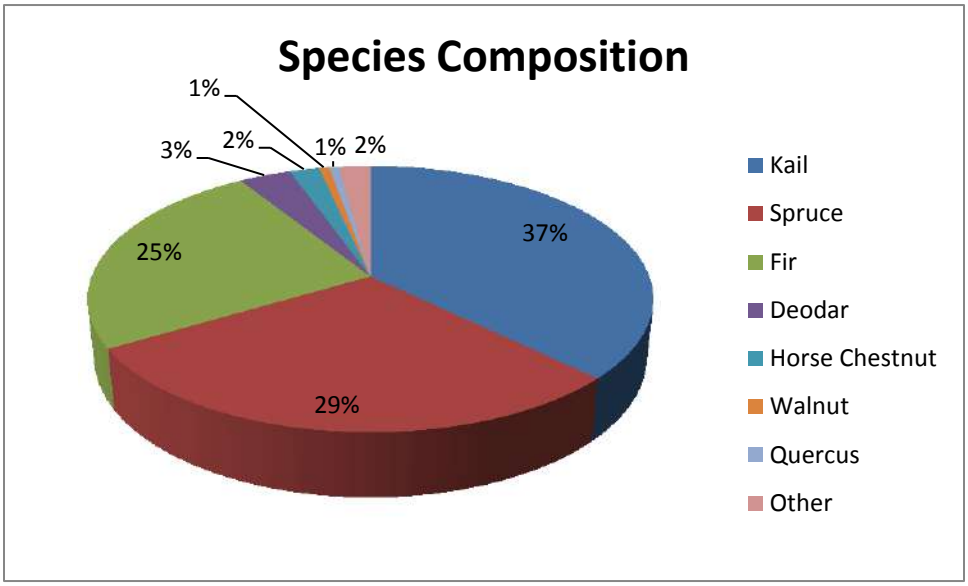

Figure 1: Growing Stock Composition by number of trees

3.2 Tree Stocking/Density

The average stocking/density was estimated at 109 trees per ha having DBH more than 5 cm. In Reserved Forests, the average number of

trees per ha was estimated at 113 whereas in Guzara Forests, the tree density was 106 trees per ha. This shows that both Guzara and reserved forests are severely degraded and poorly stocked due to over-exploitation. The detail is given in the Table 2.

Table 2: Tree Stocking/Density

S.No	**Forest Category**	**Name of Forest**	**No of trees/ha**
1	Guzara Forest	Deoli	130
		Jachha	57
		Manda Guchha	74
Average			**106**
2	Reserved Forest	Panjul	116
		Unna	110
Average			**113**
Overall Average			**109**

3.3 Stand Structure

The results of the inventory show that the forests of Siran Valley are well represented by all age classes as shown in Figure 2. About 64% of the trees fall in immature class followed by sub-mature with 24% sample trees. Thus about 88% of the trees are young and sub-mature and about 12 % of the sample trees are mature. This shows that sufficient mature trees are available in the area.

Table 3: Stand Structure

Development Stage	No of trees	%age
Young (<30 cm)	1312	63.50
Sub-mature (30-60 cm)	502	24.30
Mature (>60 cm)	252	12.20
Total	2066	100

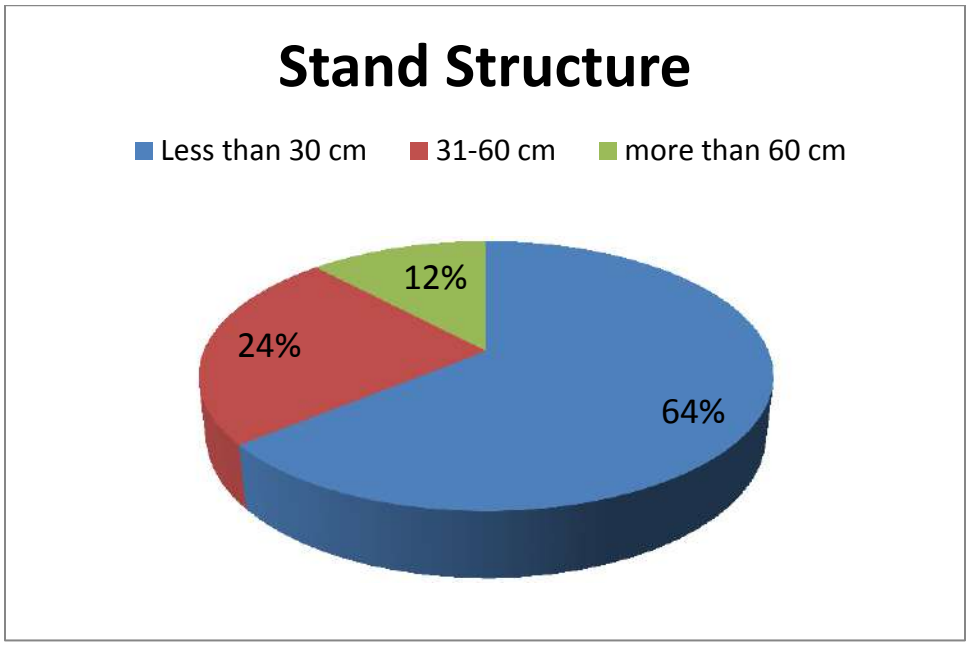

Figure 2. Stand Structure

3.4 Aboveground Carbon Stock

Aboveground biomass comprises trees and shrubs and it is the most important pool of carbon in a forest ecosystem as it is frequently subjected anthropogenic pressure and directly affected by disturbance such as logging and fire. Other carbon pools are directly or indirectly dependent on aboveground biomass. The above ground carbon stock in the forests of the SFM Project area in Siran Forest Division, Mansehra was estimated at 445,698 ton. Carbon density 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 13). 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 No 4.

Table 4: 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 5: 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**

3.5 Belowground Biomass

Carbon in the belowground biomass in coniferous forests of Siran Valley was taken as 29% of the aboveground biomass (IPCC, 2006). 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 6.

Table 6: 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**

3.6 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 7).

Table 7: 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

3.7 Soil Organic Carbon

Soil sample were collected from different forest areas of Siran Valley upto 30 cm depth. The average soil bulk density was found as 0.62 g/cm^3 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.

3.8 Total carbon stock in the Landscape

The total carbon stock in the SFM Project area of Siran Forest Division was estimated at 1,362,927 tonnes. 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 8.

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

Forest Category	Forest Area	Forest Area (ha)	AGC ton	BGC ton	Litter C ton	SOC tonnes	Total C (tonnes)	C Density (t/ha)
Reserved Forest	Panjul Reserved Forest	2,482	125,043	36,262	5,435	137,676	304,417	122.65
	Unna Reserved Forest	2,249	78,265	22,692	6,297	124,752	232,006	103.16
Guzara Forests	Deoli Guzara Forest	5,028	134,298	37,509	9,805	278,903	460,515	91.59
	Jachha Guzara Forests	1,330	38,956	11,292	1,662	73,775	125,685	94.50
	Manda Guchha Guzara Forests	2,655	69,136	20,045	3,850	147,273	240,304	90.51
Total		**13,744**	**445698**	**127800**	**27049**	**762379.7**	**1362927**	**99.17**

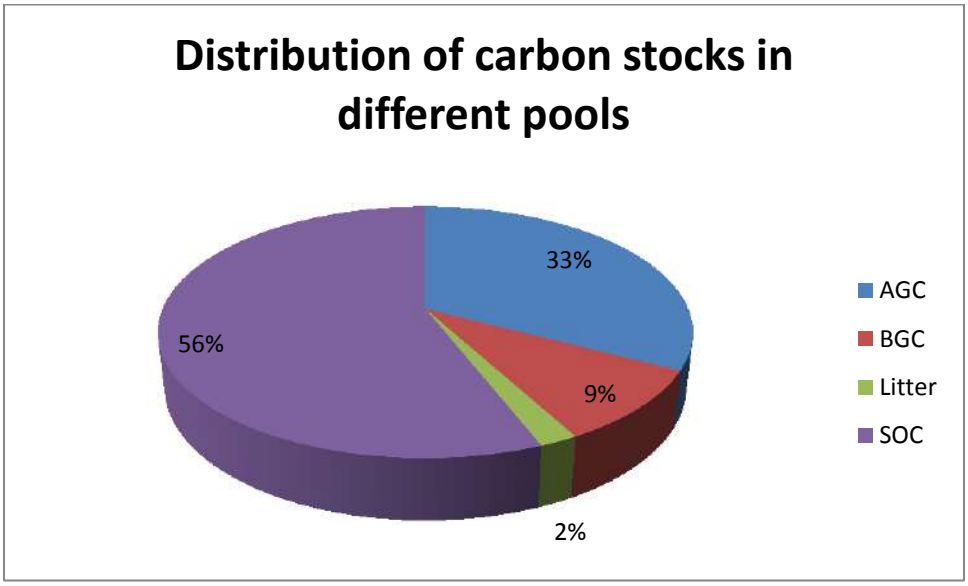

Figure 3: Distribution of carbon stocks in different pools

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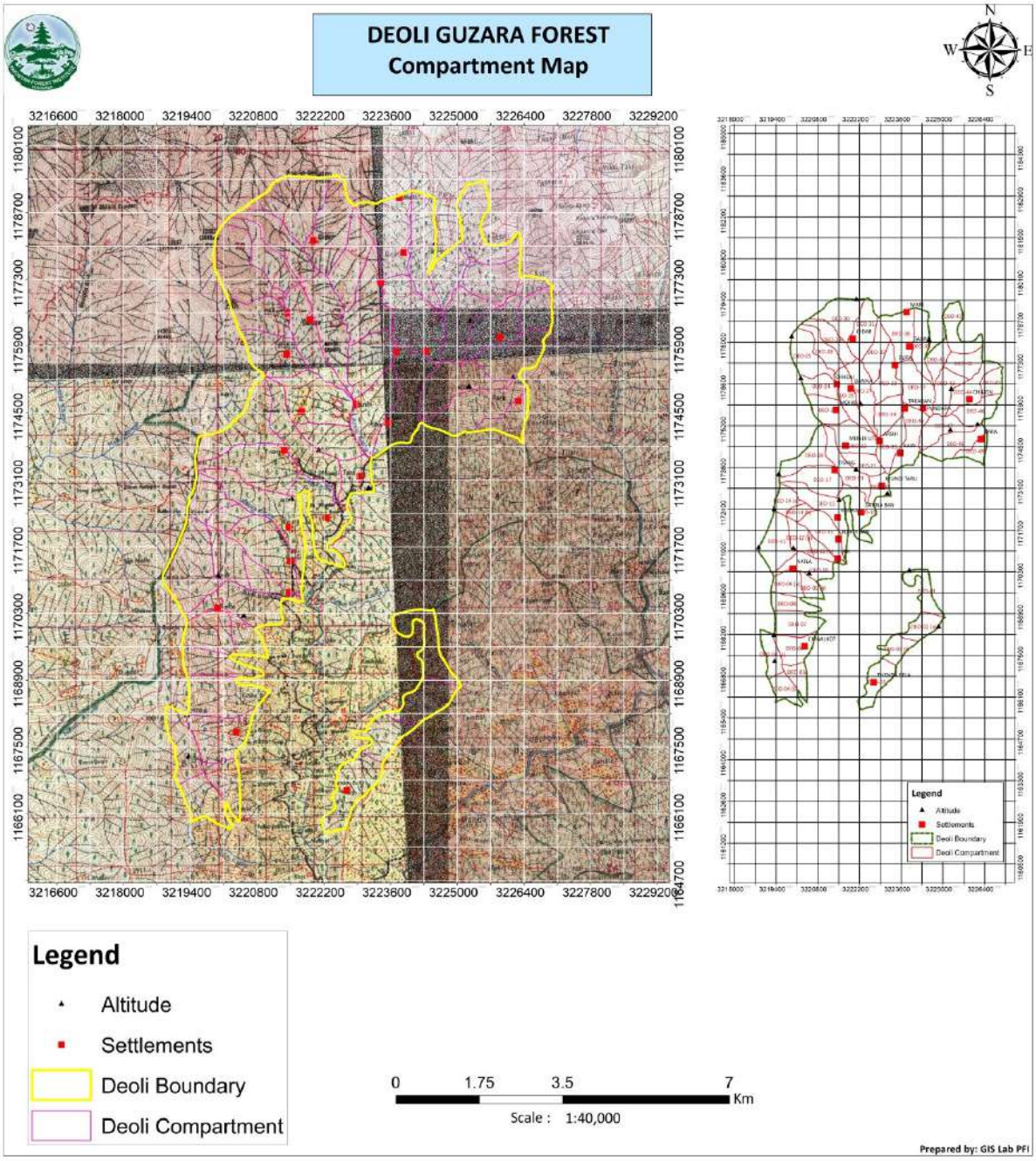
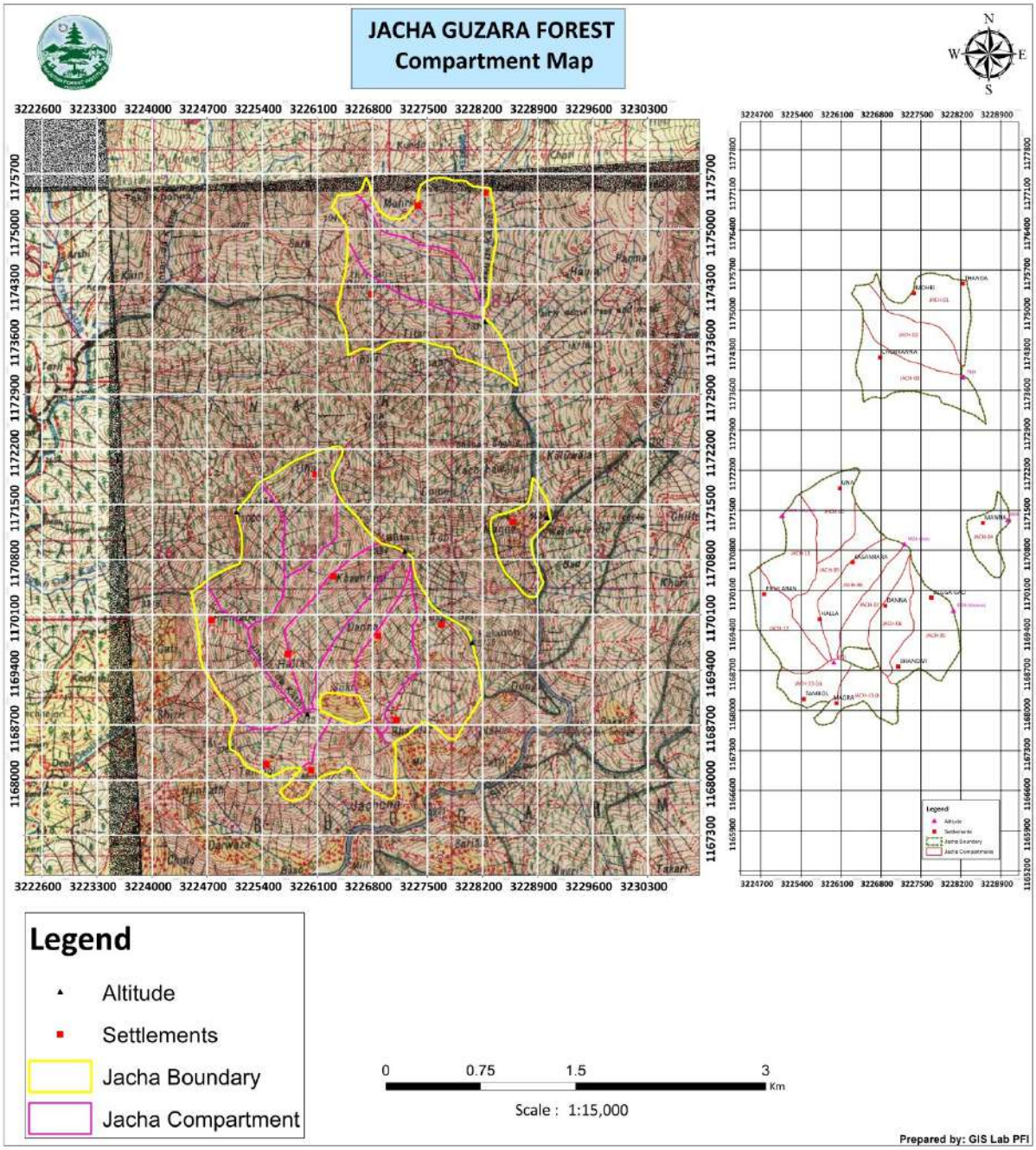
Annexure 1
Forest Maps used for Forest Inventory




JACHA GUZARA FOREST
Compartment Map
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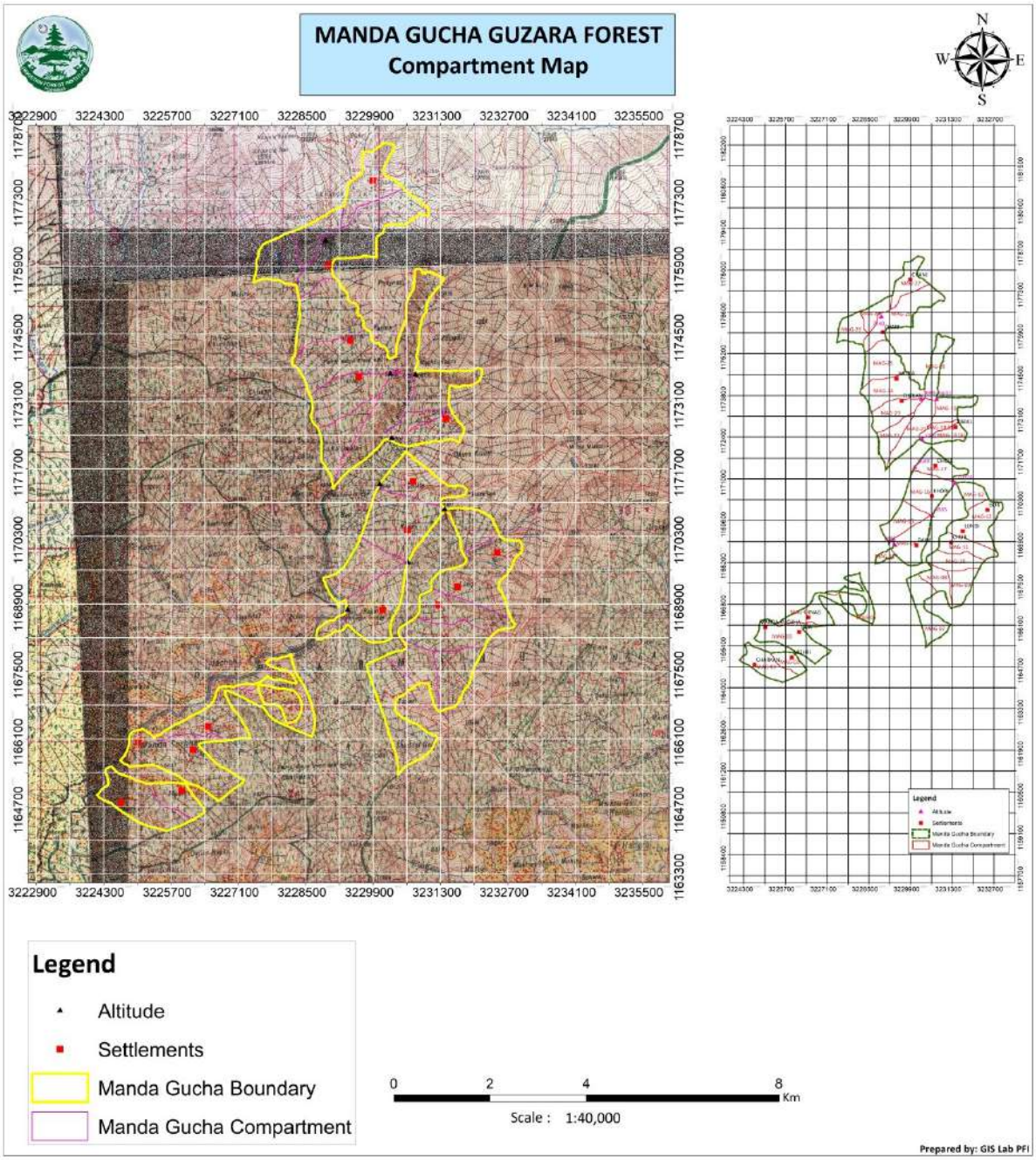
MANDA GUCHA GUZARA FOREST
Compartment Map
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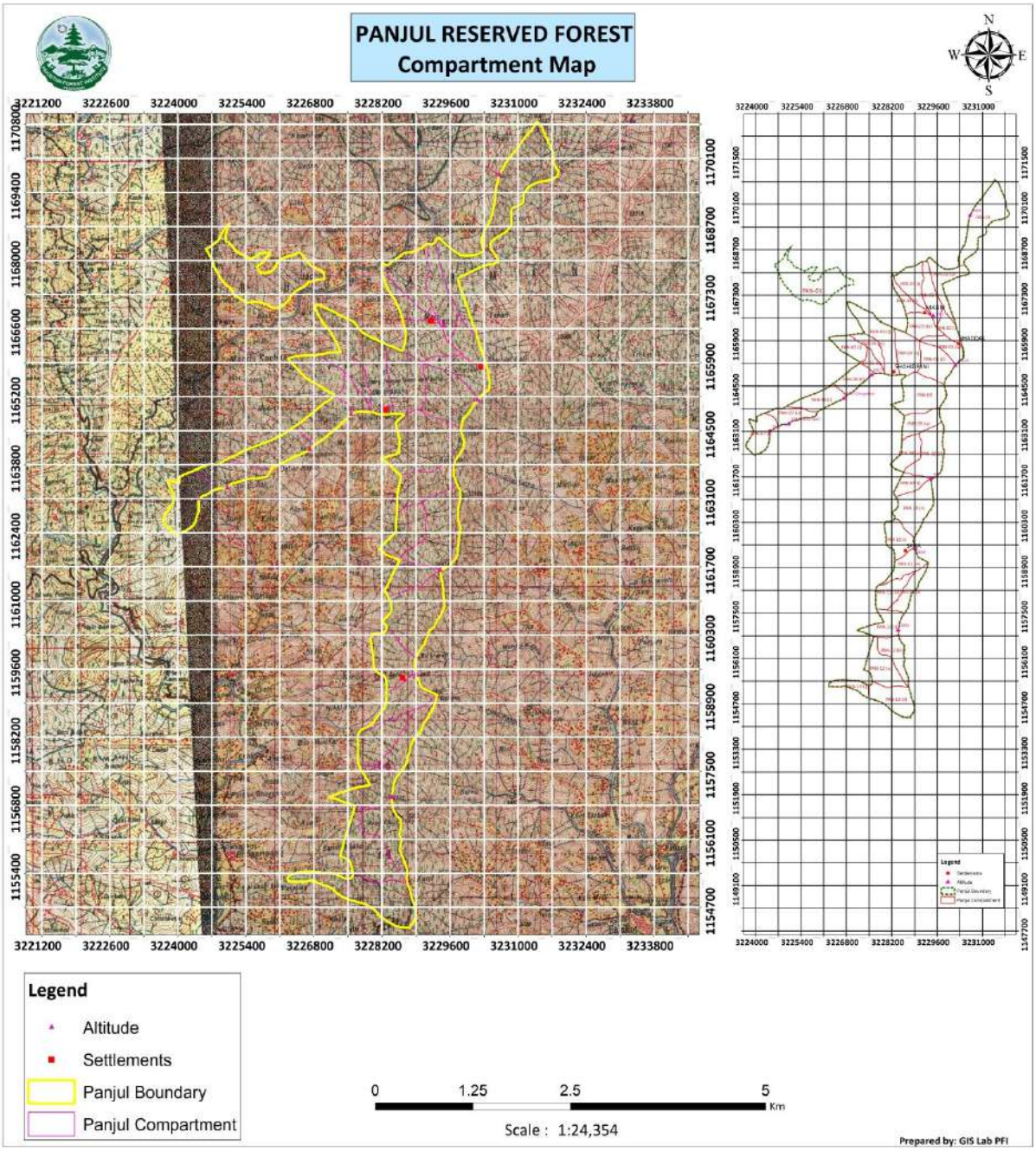
PANJUL RESERVED FOREST
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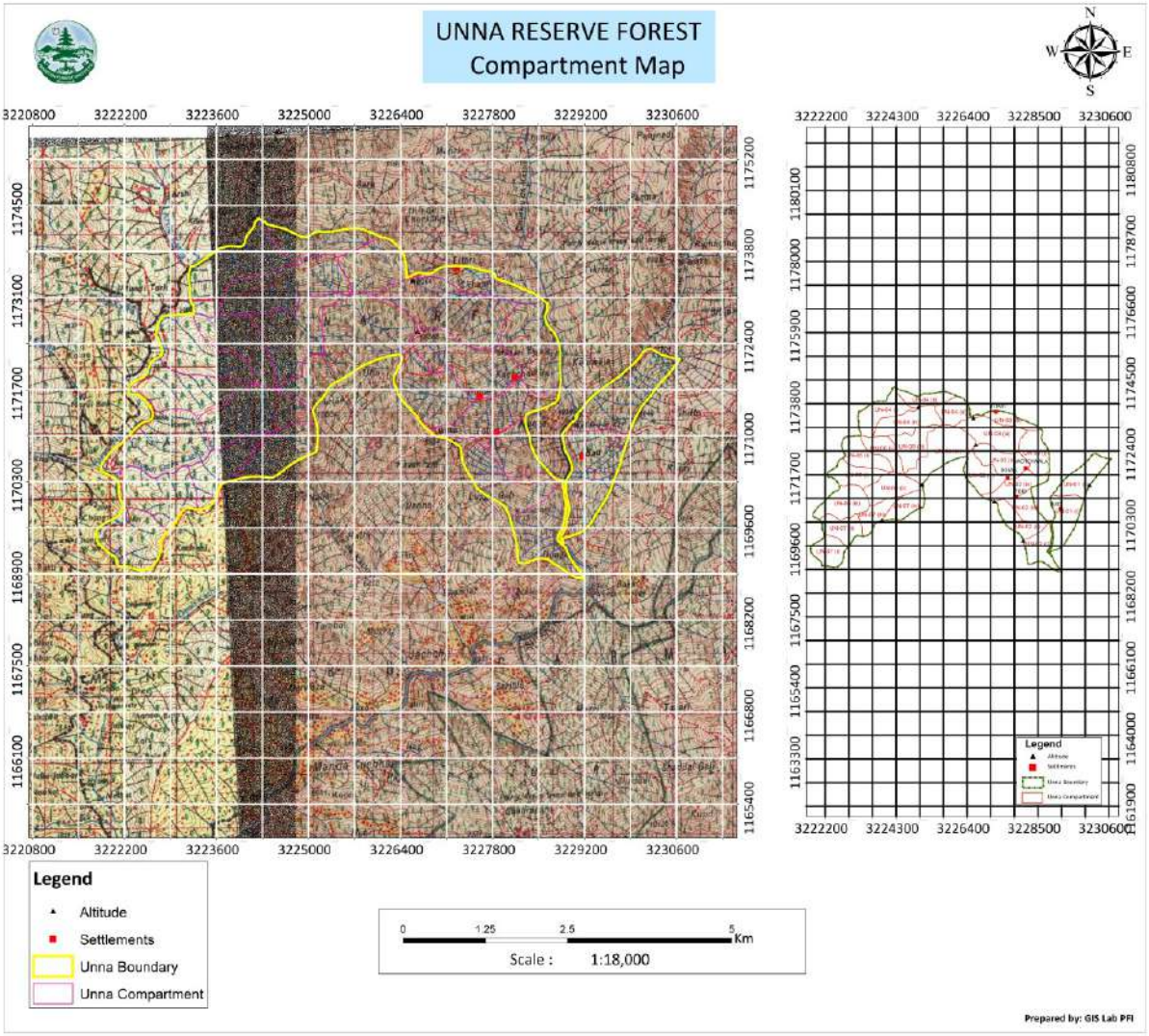
UNNA RESERVE FOREST
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