



Ministry of Climate Change



## Preliminary Report

# TEMPORAL ASSESSMENT OF HISTORIC FOREST COVER CHANGE AND THE ASSOCIATED CARBON DYNAMICS IN AYUBIA NATIONAL PARK



**PAKISTAN FOREST INSTITUTE PESHAWAR**  
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## **1. Introduction**

Ayubia National Park (ANP) is of the oldest and most important national parks in Pakistan located in Abbottabad District of Khyber Pakhtunkhwa. It was declared as national park in 1984 to protect the flora, fauna and ecosystem of this spectacular moist temperate zone. The total area of the park is 3372 ha. Kail, fir, spruce and deodar are the dominant tree species. ANP has received full protection due to its location in the tourism hotspot and full attention by the authorities.

Protected areas play important role in providing several ecosystem services including carbon sequestration, ecotourism, water regulation, biodiversity conservation etc. There is a need to properly quantify these services and assign monetary value to them to persuade policy makers to acknowledge the important role of these protected areas and declare more areas as national parks.

The current study was conducted to determine temporal changes in the forest cover in ANP and the resultant changes in carbon stock over time. The main objectives of this research study were:

- To quantify changes in forest cover of ANP at 5 years interval from 1990 to 2020.
- To determine changes in growing stock in the area since 1990.
- To quantify change in carbon stock in the area since 1990 and compare the carbon stocks of ANP with the surrounding areas.

## **2. Methodology**

The current study has two main components i.e. historic forest cover change assessment and determination of carbon stock per unit area. Two different methodologies were used for the study viz; satellite data processing and interpretation and field survey for carbon stock assessment.

### **2.1 Forest Cover Change Assessment**

A combination of GIS, GPS and RS technologies was used to detect changes in forest cover of ANP. In 1984, ANP was notified as National Park but historic satellite data of the area is available from 1990 which was considered as the baseline year for the multi-temporal assessment. Following are the steps taken for multi-temporal assessment of historic forest cover change.

- i. Multi-Temporal (Satellite) data acquisition and review of secondary information.
- ii. Data Pre-processing/preparation

- iii. Image Classification
- iv. Devising methodology for sampling for Field verification & data collection
- v. Multi-temporal change detection
- vi. Production of maps

### **2.1.1 Multi-Temporal (Satellite) data Acquisition**

In 1984, ANP was notified as National Park. 1990 will be considered as baseline for the multi-temporal assessment. Very High Resolution (VHR) or High Resolution (HR) data for three decades (1990 to 2020) was acquired. Time series of three decades were decided on the basis of availability of VHR/HR satellite data. The secondary information/data (management/working plans, reports, landuse maps etc.) were also reviewed for finalization of methodology adopted for assessment.

### **2.1.2 Data Pre-processing/preparation**

Standard pre-processing methods were adopted for preparation of satellite data for further image classification operations.

### **2.1.3 Image Classification**

Image classification techniques was finalized on the basis of quality of available satellite images. Two methodologies are widely adopted for image classification i.e.

#### **A. Object-Based Image Analysis (OBIA) or Object-Oriented Classification (OOC).**

Object-Based Image Analysis (OBIA) was carried out through image separation into objects/segments (groups of homogenous pixels) and identification of objects depending on their attributes/characteristics/ features. OOC process was based on the intrinsic values which include spectral properties, texture, shape etc. and relationships among objects which include connectivity, position to other objects.

#### **B. Field Verification/GPS based data collection followed by hybrid approach (visual interpretation of Google Earth Pro images/data).**

Visual interpretation of High Resolution (HR) and Very High Resolution (VHR) data has been recommended as one of the key approaches for forest monitoring and reporting by international committees such as the GOF-C-GOLD (2011). Visual interpretation of VHR images widely used in different forest assessments such as forest structure and biomass estimation. Examples include studies on selective forest logging and its impacts (Read et al. 2003; Furusawa et al. 2004; Pithon et al. 2013), forest species classification (Clark et al. 2005; Valérie and Marie-Pierre 2006; Kim et al. 2009; Bilous et al. 2017), tree crown identification (Garzon-

Lopez et al. 2013; Karlson et al. 2014) and biomass estimation (Hussin et al. 2014). In these studies, visual interpretation of VHR images was often used.

#### **2.1.4 Devising methodology for sampling for field verification & data collection**

Sampling structure (sample size & technique) for ground truthing and other field data collection was finalized on the basis of availability and quality of multi-temporal satellite data.

#### **2.1.5 Multi-temporal change detection**

Change detection involves the use of multi-temporal datasets to discriminate areas of forest change between dates of imaging. The classified images with forest area detected in different years were analysed for demarcation/identification of areas highlighted as changed. The yearly change in terms of area and spatial location was marked on the basis of time span.

#### **2.1.6 Production of forest cover maps**

Final maps will be produced on the basis of resultant image classification and forest change detection.

### **2.2 Carbon Stock Assessment**

Carbon stock assessment of ANP and the surrounding forest areas comprised estimation of carbon stocks in the following carbon pools:

- Aboveground Biomass
- Belowground Biomass
- Litter
- Dead Wood
- Soil Organic Carbon

#### **2.2.1 Sampling Design**

Systematic random sampling design was used for collecting data in the field. Sample plots were laid out on a geo-referenced map using a grid of 500 x500 m. A total of 135 sample plots were laid out in ANP and 72 sample plots were laid out in the surrounding forests. Thus the total sample size was 207. 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. There were three sub-plots within one plot for measurement of different carbon pools as shown in Figure 1.

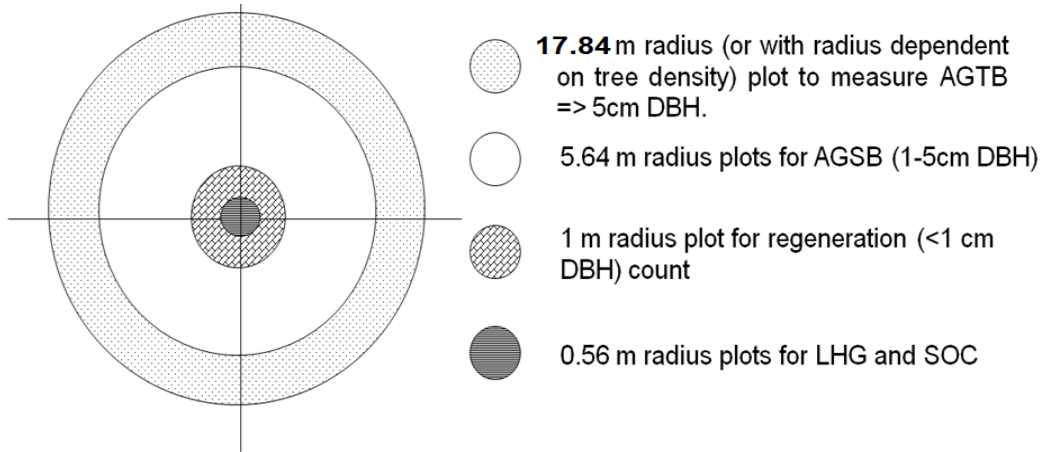


Figure 1. Nested Circular Plot

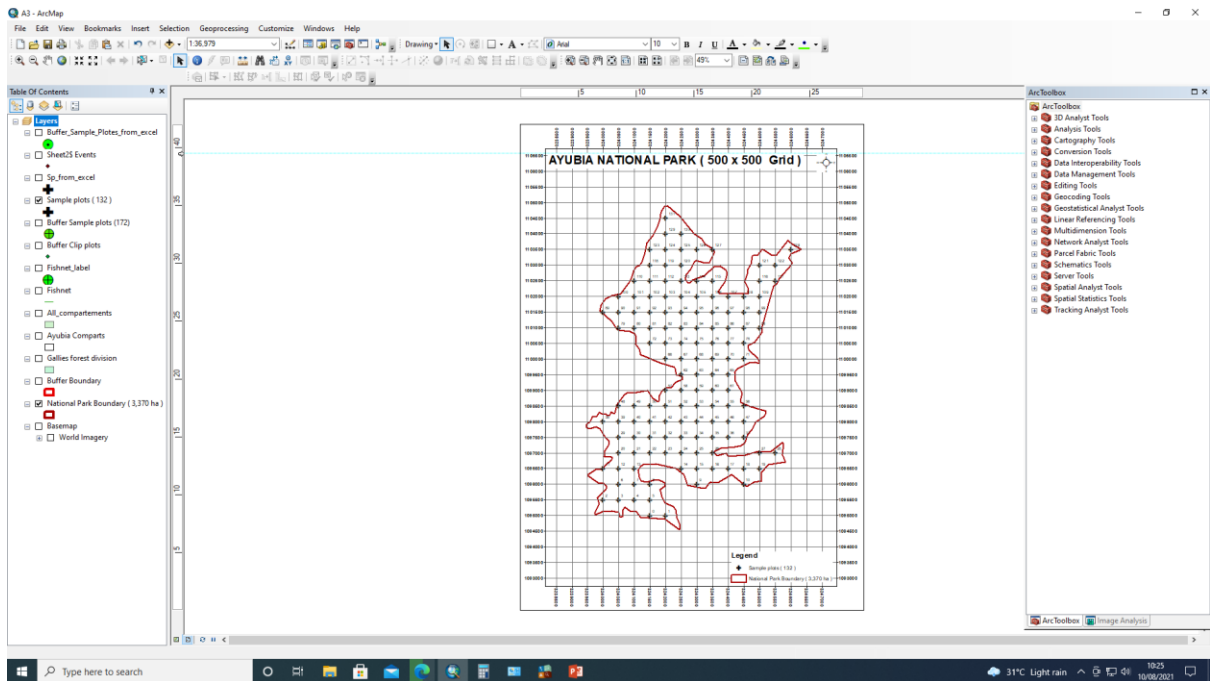


Figure 2: Sample Plots in ANP

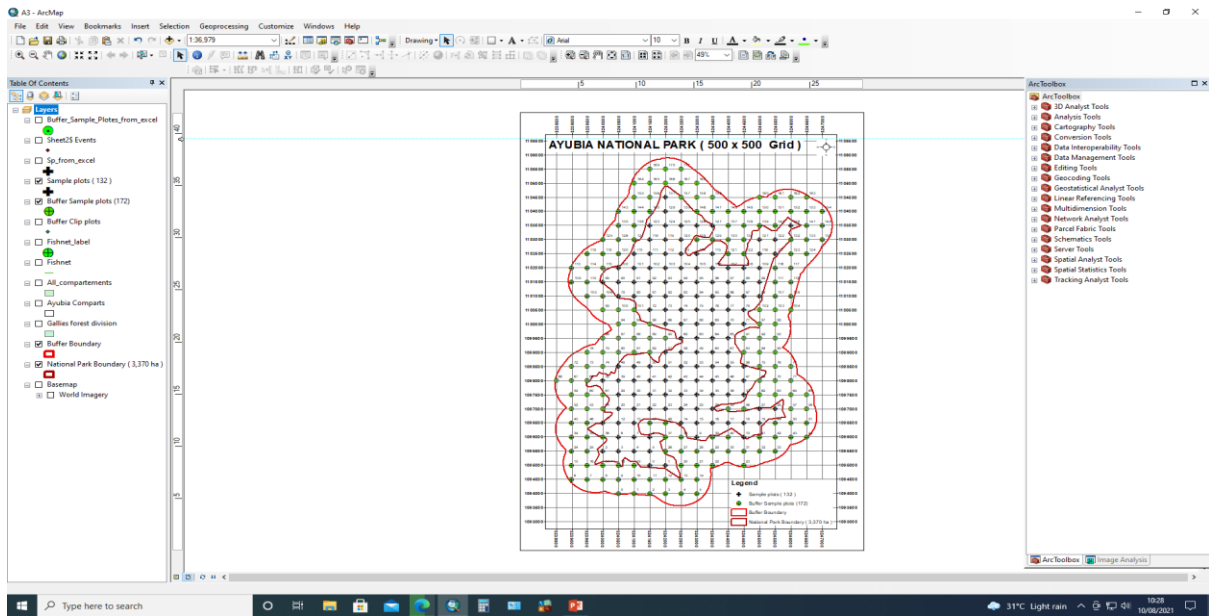


Figure 4: Sample Plots in Surrounding Area

### 2.2.2 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)  $\geq$  5cm.

### 2.2.3 Above-ground shrub Biomass (AGSB)

Second circular plot with radius 5.64 m (100 m<sup>2</sup> 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 taken to PFI for further analysis in the Lab. The samples were dried in the oven at 105°C till constant weight using a digital balance. Moisture content was determined by the following formula:

$$MC\% = (\text{Fresh Wt of sample} - \text{Dry Weight of sample}) / \text{Fresh weight of sample} \times 100$$

### 2.2.4 Leaf litter, herbs and grasses (LHG)

Third circular plot with radius 0.56 m (1 m<sup>2</sup> area) was used for measuring all leaf, litter, herbs and grasses which were dried in the oven to determine the ratio of oven-dry to fresh biomass.

### 2.2.5 Below-ground Biomass (BGM)

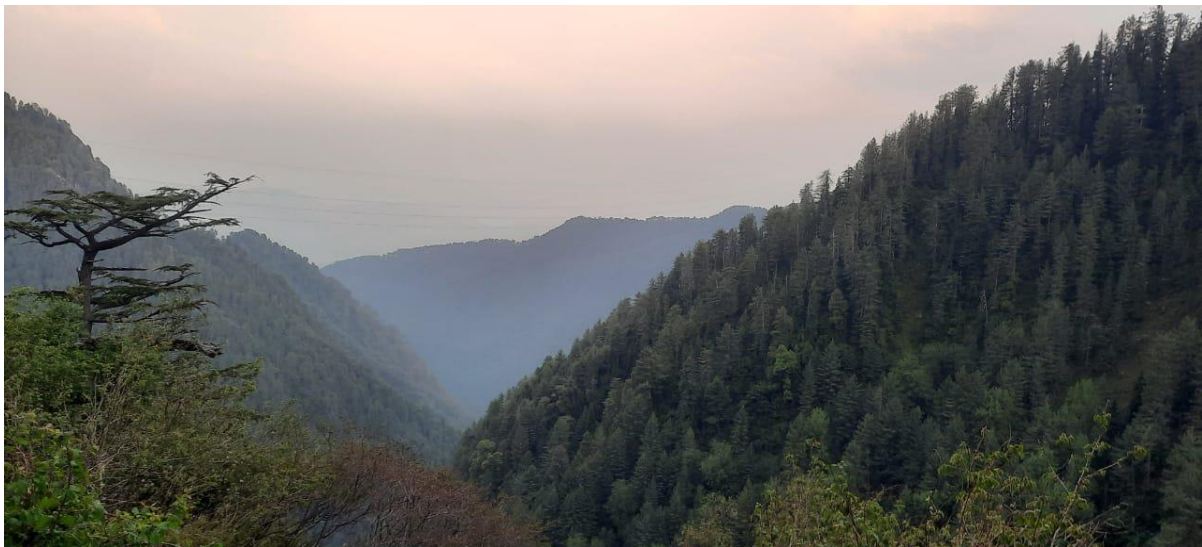
BGM was estimated using default values from IPCC Guidelines (2006). In all pools biomass was converted to carbon stock by multiplying with 0.47 as suggested by IPCC (IPCC, 2006).

### 2.2.6 Soil Organic Carbon

For measuring soil carbon, samples were collected from 0-30 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° 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:

$$\text{SOC} = \rho * d * C * 10$$

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



### 3. Results

#### 3.1 Growing Stock Composition

A total of 3,554 trees belonging to 22 different species were tallied during the field measurements. The tree species sampled predominantly consisted of conifers (83%). The remaining 17% trees were broad-leaved trees belonging to 21 different species. The species composition is shown in the Figure 2. In conifers Kail (*Pinus wallichiana*) is the dominant species (45%) followed by Fir (*Abies pindrow*) with 25%, Deodar (*Cedrus deodara*) 8% and Spruce (*Picea smithiana*) with 5% share. *Taxus wallichiana* and chirpine have only 2% and 0.3% shares in the conifers.

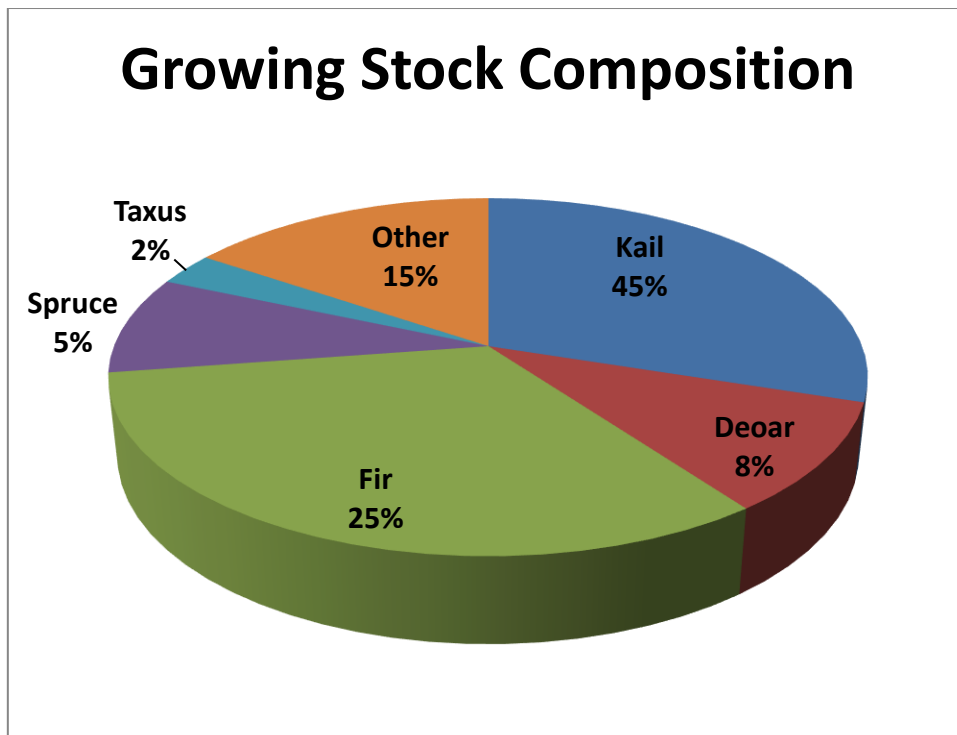
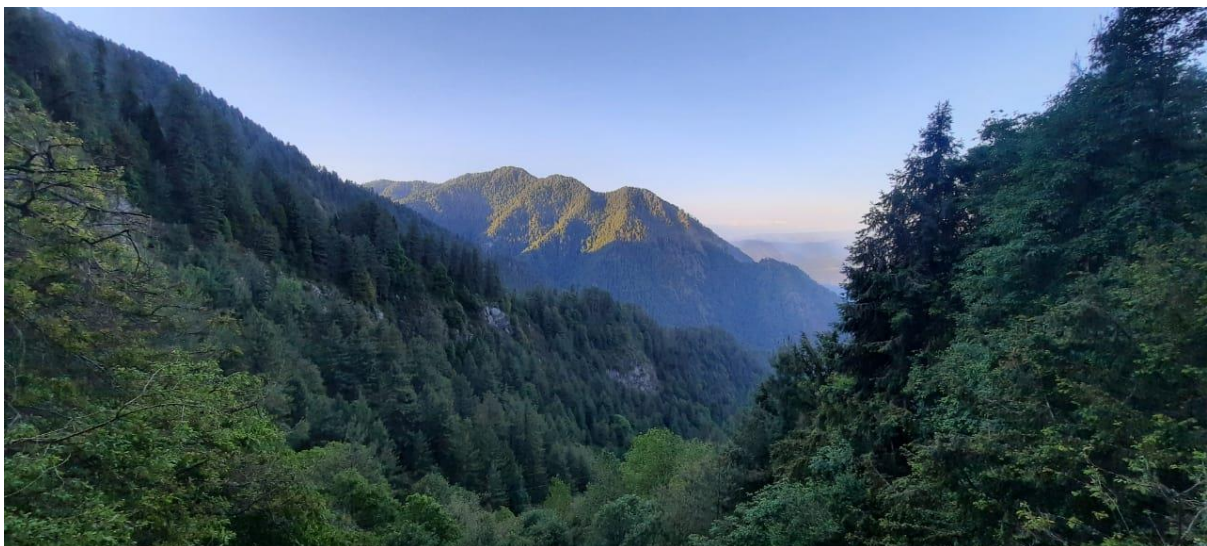


Figure 5. Growing Stock Composition by number of trees



### 3.2 Tree Stocking/Density

The average stocking/density was estimated at 645 trees per ha. Inside National Park, the average number of trees per ha was estimated at 645 whereas in the surrounding Forests, the tree density was 375 stems per ha. This shows the surrounding National Park forests are in a very good condition compared to the the surrounding forests. Local communities fulfil their needs from the surrounding forests due to which these are facing degradation.

**Table . Tree Stocking/Density**

S.No	Forest Type	No of trees/ha

1	National Park	645
2	Surrounding Forest	375

### 3.3 Stand Structure

The results of the inventory show that the forests of Ayubia National Park are well represented by all age classes as shown in Figure 3. About 65% of the trees fall in immature class followed by sub-mature with 18% sample trees. Thus about 83% of the trees are young and submature and about 17 % of the sample trees are mature.

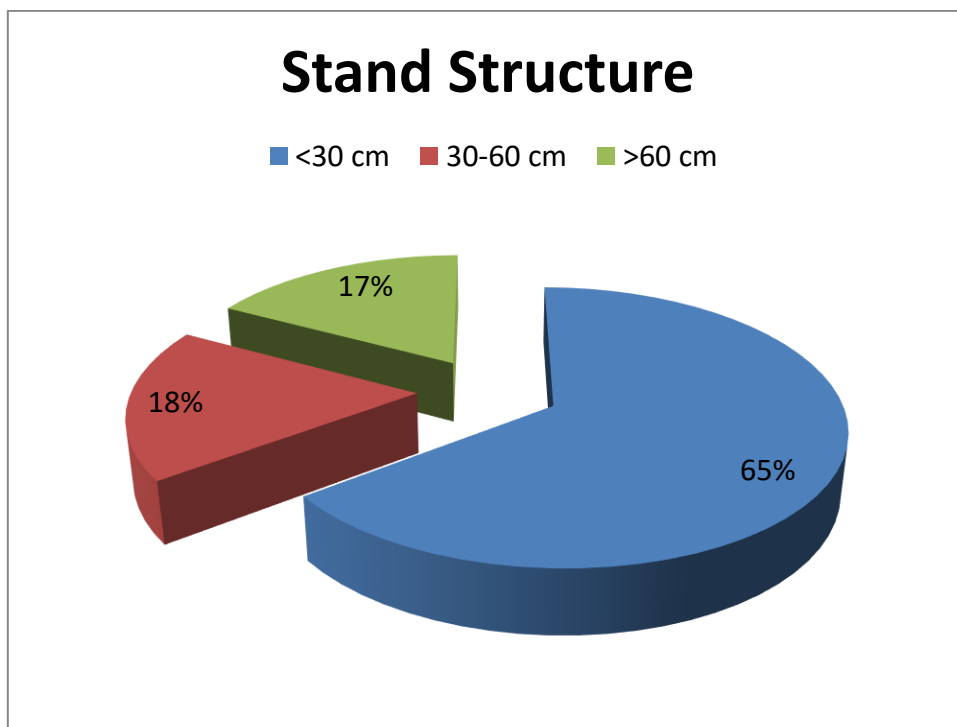


Figure 6. Stand Structure

### 3.4 Development stages of coniferous species

The stand structure of conifers is depicted in Figure 4. About 65% of the trees fall in young and 22% fall in sub-mature stages whereas only 13% mature in all coniferous species. The developmental stages of different coniferous species are shown in the Figure 5. Highest percentage of mature trees are present in spruce (17%) followed by fir (15%). Deodar and Kail have 12% and 11% mature trees respectively. The detail is given in table 7. Thus, it is clear that sufficient numbers of mature trees are present in all coniferous species. This is probably due to the prevailing ban on harvesting of green trees in the area.

# Conifers Stand Structure

<30 cm    30-60 cm    >60 cm

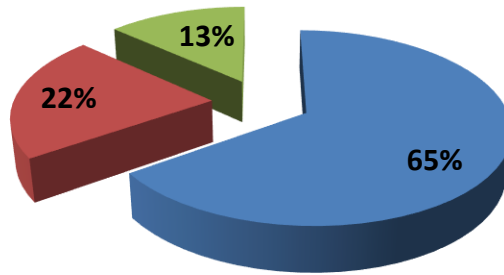


Figure 7. Stand Structure of Conifers

Table 2. Developmental Stages of Coniferous Species

Species	Young	Sub-mature	Mature
Deodar	64	24	12
Kail	65	24	11
Fir	68	17	15
Spruce	58	25	17
Bermi	63	28	9

## Species wise Stand Structure

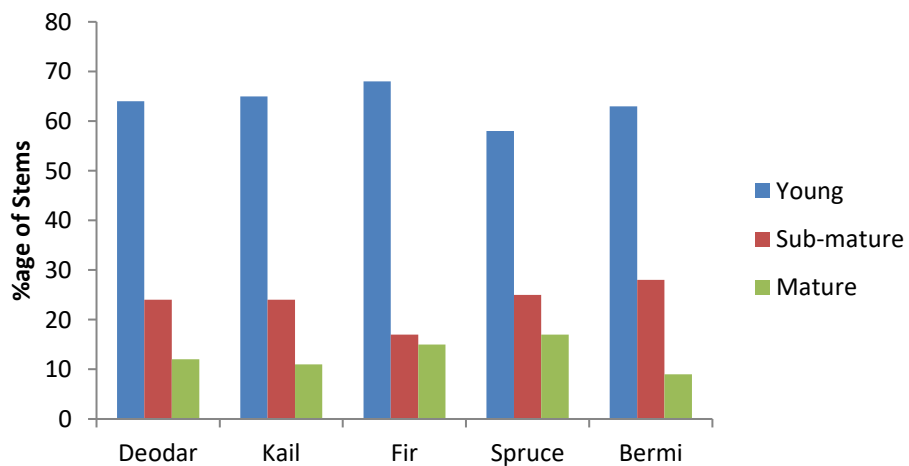


Figure 8: Development stages of coniferous species



### **3.5 Aboveground Carbon Stock**

The aboveground biomass is the most important pool of carbon in a forest ecosystem as it is subjected to changes due to anthropogenic activities. Other carbon pools are directly or indirectly dependent on aboveground biomass. The above ground carbon stock in the forests of Ayubia National Park was estimated at 414,756 ton. Carbon density was determined at 123 tonnes per ha. In the surrounding forests the above ground carbon stock is 75 t/ha.

### **3.6 Belowground Carbon Stock**

Belowground biomass carbon was derived from the aboveground carbon stock using IPCC default values (IPCC, 2006). Belowground carbon stock calculated as 30.75 t/ha in the Ayubia National Park and 18.75 t/ha in the surrounding forests. Total belowground carbon stock in the area was estimated as 103,689 tonnes.



### Identification of Species on bases of Sample Plots

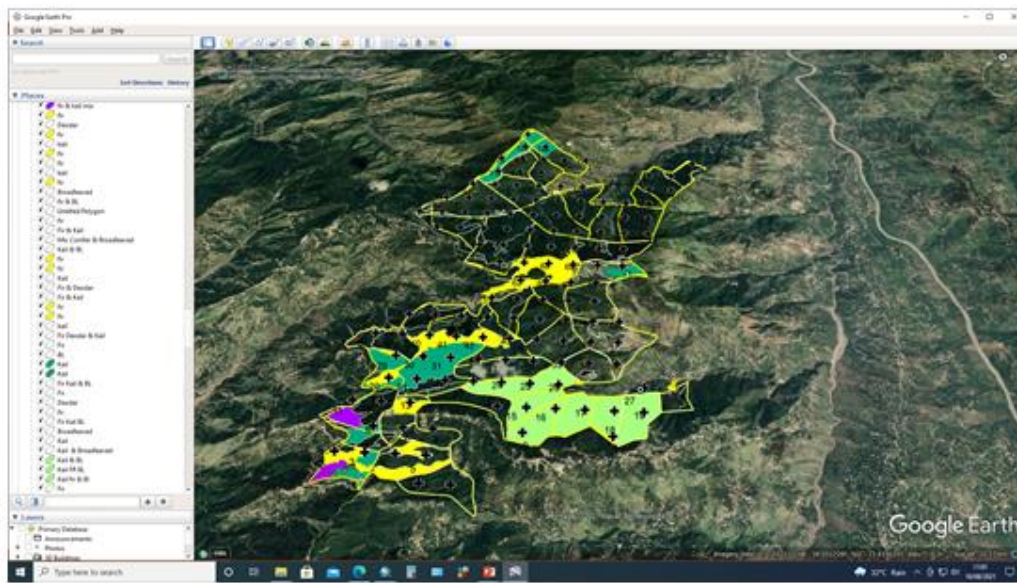
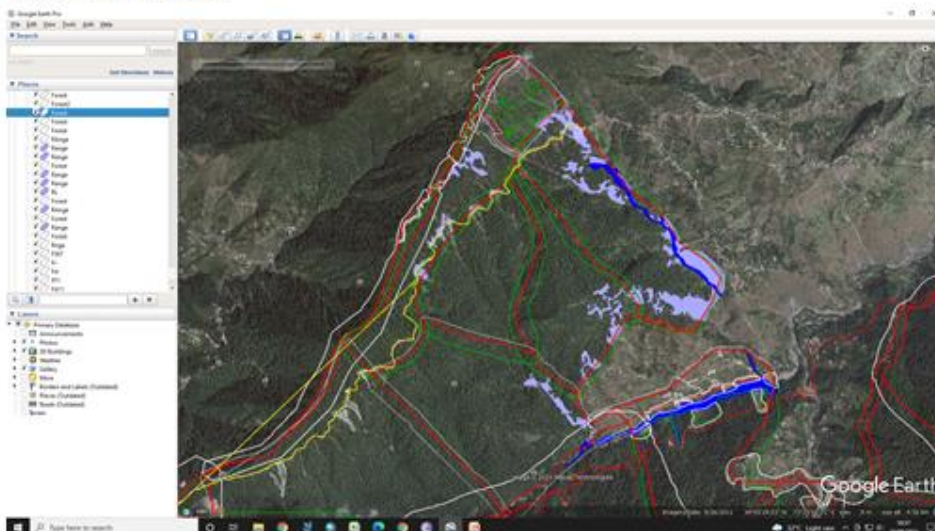


Figure No. 9: Mapping of Species

### Landcover Digitization



## Schedule of Research Activities

Duration: 9 months March-November 2021

Activity	Mar ch	April	May	June	July	Aug	Sept	Oct	Nov
Satellite Data acquisition									
Data Pre-processing/preparation									
Image classification									
Ground trothing/field verification									
Production of maps									
Field survey for carbon stock assessment									
Lab Analysis of Vegetation and Soil Samples									
Carbon data entry & analysis									
Draft Report									
Final Report									

## List of Sample Plots Laid out in Ayubia National Park

Plot No.	Location	Compart No.	X	Y	Elevatio n (m)	Aspect	Slope %	Crown Cover %
0	Ayubia	D-2(ii)	3241502	109500 0	2252	N-W	70	
1	Ayubia	D-2(ii)	3242001	109495 5	2089	S	75	85
2	Ayubia	Taaj 4(i)	3240001	109549 8	2420	S	80	50
3	Ayubia	Taak 4(i)	3240500	109549 9	2544	W	75	70
4	Ayubia	2(i)	3241000	109550 0	2351	E	85	80
5	Ayubia	D2(i)	3241499	109550	2169	N	65	

				0				
6	Ayubia	B9(i)	3240503	109599 7	2478	N	85	
7	Ayubia	1(i)	3241032	109596 0	2357	N	75	70
8	Ayubia	Darwara 1(i)	3241500	109600 0	2288	S		60
9	Ayubia	Kahu 2(iv)	3243002	109600 0	2100	S	75	80
10	Ayubia	Kahu 1(iv)	3244502	109600 0	1840	E	75	70
11	Ayubia	9(ii)	3240014	109645 7	2281	E	85	
12	Ayubia	B (9(ii))	3240500	109650 0	2537	S	70	85
13	Ayubia	Kahu 2(i)	3241000	109650 0	2287	E	90	50
14	Ayubia	Kahu 2(iii)	3242500	109649 9	2240	W-S	70	40
15	Ayubia	Kahu 2(iv)	3242997	109650 2	1958	W	75	90
16	Ayubia	Kahu 2(iv)	3243501	109649 9	1830	W	80	70
17	Ayubia	Kahu 2(i)	3244000	109650 1	1842	S	70	80
18	Ayubia	Kahu 1(i)	3244483	109637 9	1880	S	85	60
19	Ayubia	Kahu 1(ii)	3244998	109650 0	1905	S	75	65
20	Ayubia	9(iii)	3240501	109699 7	2504	N	80	75
21	Ayubia		3241000	109700 0	2349	N	60	70
23	Ayubia	Kahu 2(ii)	3241998	109699 9	2019	N	75	
24	Ayubia	Khahu 2(ii)	3242500	109700 1	1935	S	75	
26	Ayubia	Kahu 2(ii)	3243500	109700 1	1760	S	75	80
27	Ayubia	Kahu 1(iv)	3245003	109700 3	1523	S	75	80
28	Ayubia	Kahu 1(iv)	3245503	109700 0	1468	S-E	80	60
29	Ayubia	Bagan 9(iii)	3240500	109750 0	1893	N	80	70
31	Ayubia		3241448	109754 8	2347	S	95	20
33	Ayubia	Kahu 3(3)	3242543	109754 6	1819	S	90	30
34	Ayubia	Kahu 3(iii)	3242965	109752 5	1786	S	90	85
35	Ayubia		3243500	109750 0	1710	S	80	85
37	Ayubia		3244460	109760	1877	S	90	40

				6				
38	Ayubia		3240000	109800 0	2347	E	95	80
39	Ayubia		3240500	109800 0	2383	N	80	80
41	Ayubia	Kahu 3(i)	3241519	109808 1	2385	N	90	40
42	Ayubia	Kahu	3242000	109800 0	2349	S	80	50
43	Ayubia	Kahu 3(3)	3242500	109800 0	2342	S	30	70
46	Ayubia	Kahu 5(iii)	3244000	109800 0	2254	S	80	10
47	Ayubia	Kahu 5(iii)	3244500	109800 0	2338	S	85	0
48	Ayubia	Bagan 11(i)	3240535	109851 4	2304	N	90	60
49	Ayubia	Bagan 11(ii)	3241050	109846 2	2563	W	90	50
50	Ayubia	Kahu	3241489	109856 8	2547	N	75	70
51	Ayubia	Kahu 3(ii)	3242006	109850 0	W	85	80	
52	Ayubia	Bagan 8(ii)	3242461	109853 2	2169	S	85	60
54	Ayubia	Kahu 5(iii)	2543500	109850 0	2336		90	50
55	Ayubia	Kahu 5(iii)	3244000	109850 0	2337	S	90	
56	Ayubia	Kahu 5	3244423	109845 5	2129	E	95	60
57	Ayubia	Bhagan 8(ii)	3242004	109897 9	2279	N	75	
58	Ayubia	Bagan 8(iii)	3242500	109900 0	2290	S	75	90
59	Ayubia	Bagan 8(iii)	3243000	109900 0	2543	S	80	70
60	Ayubia	Kahu 5(ii)	3243576	109901 3	2586	S	90	45
61	Ayubia	Kahu 5(iii)	3244000	109900 0	2337	S	85	70
62	Ayubia	Water area	3242500	109950 0	2370	N-W	90	50
63	Ayubia	Bagan 8(i)	3243000	109950 0	2343	S	70	70
64	Ayubia		3243500	109950 0	2490	S	75	20
65	Ayubia		3244000	109950 0	2396	S	70	50
66	Ayubia	B (7)	3241991	110000	2504	N	80	70
67	Ayubia	B(7)	3242539	109998 5	2513	E	80	45
68	Ayubia	Water area	3243000	110000 0	2369	SE	85	70

69	Ayubia		3243500	110000 0	2686		80	10
70	Ayubia		3243777	109998 2	2796	S	95	40
71	Ayubia	Baghan 7	3244500	110000 0	2795	N	80	80
72	Ayubia	B(4)	3241500	110050 0	2444	E	70	60
73	Ayubia	B(4)	3242001	110050 2	2479	W	60	60
79	Ayubia		3240500	110100 0	2390	N	90	80
81	Ayubia	B(3)	3241500	110100 2	2155	W-S	75	70
82	Ayubia	B(4)	3242000	110100 0	2482	S	75	70
83	Ayubia		3242509	110092 7	2204	N	95	95
85	Ayubia		3243507	110098 7	2248	SE	90	80
87	Ayubia	Bakit 3(i)	3244497	110099 9	2076	NW	90	60
89	Ayubia	B(4)	324003	110150 5	2331	N	75	60
90	Ayubia	B(3)	3240497	110150 0	2158	W	65	60
91	Ayubia	B(3)	3240998	110154	1980	S	70	65
92	Ayubia	B(4)	3241497	110150 1	1937	N	75	65
93	Ayubia	B(4)	3241955	110151 3	1910	E	75	65
95	Ayubia		3243003	110150 1	1591	W	85	90
96	Ayubia		3243499	110149 9	2223	S	70	86
97	Ayubia		3244000	110150 0	1978	SE	80	70
98	Ayubia	Bk	324449	110154 4	1936	N	90	85
100	Ayubia	Bagan 2	3240498	110200 2	2366	N.E	80	70
101	Ayubia	Bagan ii	3241051	110187 5	2107	s	75	60
102	Ayubia	Bagan (2)	3241500	110200 0	2224	E.S	70	60
103	Ayubia	Bakot 4(ii)	3242002	110200 1	1904	S	60	60
104	Ayubia	BK3(iii)	3242501	110199 8	1739	S	60	25
105	Ayubia	BK5(ii)	3243003	110200 2	1860	S	85	70
106	Ayubia	Barkot 3(ii)	3243502	110200 0	1924	NE	85	60
107	Ayubia		3244000	110199	1930	NE	85	55

				6				
108	Ayubia		3244495	110200 2	1793	NW	60	70
110	Ayubia	Bagan 2	3240996	110249 8	2496	E-S	75	65
111	Ayubia	BK 4(ii)	3241537	110251 0	2258	S	85	65
112	Ayubia	BK 4(ii)	3241891	110245 5	2015	E-S	80	65
113	Ayubia	Bake 4(iii)	3242509	110249 7	1848	W-E	75	50
115	Ayubia	BK 3(ii)	3243456	110248 3	1650	S	90	75
116	Ayubia		3245000	110250 0	2334	N	80	70
117	Ayubia		3245507	110249 9	2106	N	90	50
118	Ayubia	B 4(i)	3224150 2	110300 1	2455	S	80	60
120	Ayubia	Bakot 5(ii)	3242626	110303 9	2098	E-W	65	50
121	Ayubia	Bakot 1(ii)	3245000	110300 0	2307	W	75	20
122	Ayubia	Bakot 1(ii)	3245500	110300 0	2305	W	90	30
123	Ayubia	BK 4(i)	3241496	110349 8	2542	E-S	80	60
124	Ayubia	Bakot 4(ii)	3242000	110350 0	2335	S	90	80
125	Ayubia	BK 5(ii)	3242499	110349 9	3297	E-W	84	50
126	Ayubia	BK 5(iii)	3242989	110350 1	2082	N-E	70	25
127	Rampagwar i	Bakot 5(iii)	3243500	110350 0	1772	NE	76	
128	Ayubia		3246000	110350 0	1936		90	30
129	Ayubia	BK 5(ii)	3242000	110399 8	2539	E-S	80	65
130	Ayubia	Bakot 5(iii)	3242500	110400 0	2290	N-E	50	85
131	Ayubia	BK 5(i)	3241915	110450 3	2819	E	80	40