GREEN HOUSE GAS INVENTORY OF FORESTRY SECTOR-AZAD JAMMU & KASHMIR

Ministry of Climate Change

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REPORT PREPARED BY WWF-PAKISTAN

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ACRONYMS

AD	Activity data
AGB	Above Ground Biomass
AJK	Azad Jammu & Kashmir (autonomous territory)
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BGB	Belowground Biomass
BGC	Belowground Carbon
CD	Community Development
CCF	Chief Conservator Forest
CF	Conservator Forest
CO2	Carbon Dioxide
COP	Conference of Parties
CP	Conference of Parties (Decision references)
CSO	Civil Society Organization
CSV	Comma-separated Values
DBH	Diameter at Breast Height
DEM	Digital Elevation Model
D-H	Diameter-Height
DW	Dead Wood
EF	Emission Factor
Emiss.	Emissions
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
FD	Forest Department (provincial)
FOSS	Free and Open-Source Software
FPIC	Free, prior and informed consent
FREL	Forest Reference Emissions Levels
FRL	Forest Reference Levels
FSMP	Forestry Sector Master Plan
GB	Gilgit-Baltistan (autonomous territory
GCISC	Global Change Impact Studies Centre
GCP	Ground Control Point
GDEM	Global Digital Elevation Model
GHG-I	Greenhouse Gas Inventory
GIS	Geographic Information System
GOP	Government of Pakistan
GPS	Global Positioning System
GPS	Global Positioning System
GUI	Graphical User Interface ha Hectare (1 ha = 10,000 m2)
HR	High Resolution

ICIMOD	International Centre for Integrated Mountain Development
ICT	Islamabad Capital Territory (federal capital territory)
INGO	International Non-Governmental Organization
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
IUCN	International Union for Conservation of Nature
km / km2	Kilometer / Square kilometer
KP	Khyber Pakhtunkhwa (province)
LCCS	FAO's Land Cover Classification System
LiDAR	Light Detection and Ranging
LULC	Land Use Land Cover
LULUCF	Land Use, Land Use Change and Forestry
MBIGS	Multiple benefits, impacts, governance, safeguards
MMRV	Monitoring & Measurement, Reporting and Verification
MMU	Minimum Mapping Unit
MOCC	Ministry of Climate Change
MOE	Ministry of Environment
MRV	Measurement, Reporting and Verification
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
NCCA	National Climate Change Authority
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NGO	Non-governmental Organization
NRP	National REDD+ Program
NSC	National REDD+ Steering Committee
NSDI	National spatial data infrastructure
NTFP	Non-Timber Forest Product
NUST	National University of Sciences and Technology (NUST)
O&M	Operationalization and Maintenance
OBIA	Object Based Image Analysis
OGC	Open Geospatial Consortium
OIGF	Office of Inspector General of Forests
OLI	Operational Land Imager
PAMs	REDD+ Policies and Measures
PB	Punjab (province)
PBI	MS Power BI (A Microsoft Data Analysis Software)
PES	Payment of Ecosystem Services
PFI	Pakistan Forest Institute
PSU	Primary Sampling Unit
QA	Quality assurance

QC	Quality control
QGIS	Quantum GIS (Open-Source GIS Software)
R&D	Research & Development
REDD	Reducing Emissions from Deforestation and Forest Degradation
REDD+	Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
Rem.	Removals
RF	Removal Factor
ROI	Regions of Interest
R-PP	Readiness Preparation Proposal
RS	Remote Sensing
SAGA	System for Automated Geoscientific Analysis
SAR	Synthetic Aperture Radar
SCP	Semi-Automatic Classification
SD	Sindh (province)
SECP	Securities & Exchange Commission of Pakistan
SIS	Safeguard Information System
SLMS	Satellite Land Monitoring System
SOC	Soil Organic Carbon
SOP	Survey of Pakistan
SPOT	Satellite Pour l'Observation de la Terre (French satellite image provider)
SSL	Secure Sockets Layer
SSU	Secondary Sampling Unit
TWG	Technical REDD+ Working Group
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	The United Nations Framework Convention on Climate Change
US	The United States of America
USGS	US Geographical Survey
UTM	Universal Transverse Mercator (coordinate system)
VHR	Very High Resolution
WCS	The Open Geospatial Consortium Web Coverage Service Interface Standard
WWF-Pakistan	World Wide Fund For Nature

EXECUTIVE SUMMARY

The sub-national GHG-Inventory aims to contribute to the implementation of the NFMS and to determine the performance against the national FREL and FRL. Specific objectives of the assignment are; to assess the forest carbon stock for the reference period of 2016-2020; assess the carbon emissions from deforestation and forest degradation and removals from enhancement of carbon stocks for the reference period of 2016-2020; provide sub-national level figures for reporting on the national contribution to the mitigation of climate change, and; access the results-based REDD+ Finance for reducing emissions.

The Sub-national Green House Gas Inventory (GHG-I) report of AJ&K covers the total area of AJ&K i.e., 13,297 km^2 as reported under the NFMS 2020.

For the current Sub-National GHG-Inventory methodologies developed during the NFMS and FREL/ FRL 2020 were adopted with slight adjustments. National definition for Forest (2017) and national definition for forest degradation (2021) were adopted for generation of activity data, forest inventory and development of emission factors.

The SLMS part included acquisition of Landsat-8 imageries for 2016 and 2020, pre-processing of imageries, LULC change analysis using the NFMS and FREL/ FRL 2020 methodologies and approaches. For the assessment of the forest degradation Spectral Mixture Analysis was adopted using the forest remaining forest for the reference period of 2016- 2020.

For the forest inventory the total national level calculated number of sample plots was 2012 (404 clusters) out of which a total of 1526 plots (326 clusters) were surveyed. In AJK the total calculated sample plots were 244 (49 clusters) out which 191 plots (43 clusters) were accessible and surveyed.

OpenForis Collect and MS Power BI software were used for data storage and processing. For tree height assessment Diameter-Height models were developed for most of the surveyed species. For aboveground tree biomass calculation existing local models developed by Ali et al 2017, 2019 and 2020 were used covering 63% of the surveyed tree species. For the remaining species the allometric equation developed by Chave *et al*. (2005) was used. Regarding carbon assessment all the IPPC recommended five carbon pools (Aboveground Biomass, Belowground Biomass, Deadwood, Litter, and Soil Organic Carbon) were considered for the overall carbon densities. For Emissions/ Removal factors for deforestation, forest degradation and enhancement the SOC pool was not considered due to insignificant changes during the reporting period of four years. The Emissions/ Removal Factors were calculated for each forest type.

The total forest cover for 2016 was found as 617,211 ha and in 2020 as 618,460 ha with a slight increase of 1249 ha. The total carbon stock in AJK's forests was estimated as 58.37 million tons (including soil organic carbon) for 2020 with an average carbon density of 94.45 t/ha.

The total area of deforestation in AJK during 2016-2020 was assessed as 612 ha with an average annual rate of deforestation as 153 ha. The highest deforestation was found in subtropical broad-leaved forest (156 ha) followed by subtropical pine forest (149 ha) and moist temperate forest (124 ha).

Analysis of forest degradation and improvement in forest cover density of forests remaining forests during 2016-2020 showed a total degradation of 35,202 ha and a total improvement in forest cover density of 73,686 ha with a net balance of improvement in forest cover densities of 38,483 ha. Highest degradation was found in Moist Temperate Forests (47%), followed by Subtropical Pine Forest (27%) and Sub-Tropical

Broad-Leaved Forest (18%). Similarly, highest improvement was also found in Moist Temperate Forest (37%) followed by Sub-tropical Pine Forest (32%), and Sub-tropical Broadleaved Forest (27%).

Enhancement due to reforestation and afforestation during the period 2016-2020 was assessed as 856 ha with an average annual enhancement rate of 214 ha. The highest enhancement was found in Sub-Alpine Forest (213 ha) followed by Subtropical Broad-Leaved Forest (177ha) and Moist Temperate Forest (176 ha).

Total emissions from deforestation were estimated as 0.08 million tons of CO_2e between 2016 and 2020. The largest share of CO_2 emissions originated from moist temperate (35%), followed by subtropical Chir pine (24%), and dry temperate forest (22%).

Total emissions from forest degradation were estimated as 3.37 million tons CO_2e during 2016-2020 and the total removals from improvement in forest cover density was estimated as 5.80 million tons CO_2e with a net removal of 2.43 million tons of CO_2e.

Total removal from enhancement due to reforestation and afforestation was estimated as 0.12 million tons of CO_2e for the normal age of the forest. However, for the four-year period (2016 to 2020) the total removals from enhancement came to be 0.009 million tons of CO2e, with 30% removals originating from Moist Temperate Forests, 26% from Sub-Alpine Forests, 17% from Sub-Tropical Chir Pine Forest and 15% from Dry Temperate Forest.

Overall, a total of 2.335 million tons of CO_2e have been sequestered from reforestation, afforestation and improvement of forest cover density during 2016 to 2020 in AJK.

1. INTRODUCTION

1.1. Brief introduction of the State of Azad Jammu and Kashmir (AJK)

The state of Azad Jammu and Kashmir is situated between longitude 73º – 75º and latitude 33º – 36º having a total area of 13,297 square kilometers. It falls within the Western Himalayan range mainly having hilly and mountainous terrain with altitude ranging from 360 meters in the south to 6325 meters in the north. From climatic point of view AJK has dry sub-tropical climate in the south while moist temperate in the north. Average annual rainfall ranges from 1000 mm to 2000 mm (with 30% to 60% precipitation in the northern parts, mostly snow) (Government of AJK 2014). Average maximum temperature ranges from 20°C to 32°C while the average minimum temperature range is 04°C to 07°C (Government of AJK 2014). Administratively the AJK State is divided in to three divisions and ten districts. Total area of AJK is Total population of AJK is 4.361 million (Government of AJK 2014). Major rivers flowing through AJK are Jhelum, Neelum and Poonch Rivers. From forest point of view AJK is divided into five main forest types; Sub-Alpine, Dry Temperate, Moist Temperate, Sub-Tropical Chir Pine, Subtropical broad leaved (Scrub).

1.2. Objectives of the Green House Gas Inventory

The Green House Gas Inventory of forestry sector of AJK has been conducted regarding implementation of the NFMS and determining the performance against the national FREL/ FRL. Specific objectives of the assignment are;

- To assess the carbon stock in the forests of AJK for 2016 and 2020;
- To assess the carbon emissions from deforestation and forest degradation and removals from enhancement of carbon stocks during the reference period of 2016-2020;
- To provide sub-national figures for reporting on the national contribution to the mitigation of climate change;
- To access results-based REDD+ Finance for reducing emissions;

1.3. Process adopted for the GHG-Inventory

The GHG-Inventory went hand in hand with the development of the Sub-NFMS by adopting the following stepwise process.

1.3.1. Adjustment and adoption of the national standards

1.3.1.1. Definition of Forest

The national definition of forest (2017) was adopted for this assignment. It defines forest as “A minimum area of land of 0.5 ha with a tree crown cover of more than 10 % comprising trees with the potential to reach a minimum height of 2 meters. This will also include existing irrigated plantations as well as areas that have already been defined as forests in respective legal documents and expected to meet the required thresholds as defined in the national definition for Pakistan.”

1.3.1.2. Deforestation

As recommended by the National FREL/ FRL Submission (2020) the FAO (2015) definition of the deforestation was adopted for the current Sub-national Forest Carbon Stocks Assessment. Deforestation is defined as “the direct human induced conversion of forest to non-forest (UNFCCC) or the permanent reduction of the tree canopy cover below the minimum 10% threshold” (FAO, 2015). A minimum mapping unit of 0.5 ha has been applied for the deforestation mapping (MoCC, 2020).

1.3.1.3. Definition of Forest Degradation

The national definition of forest degradation was developed and agreed during the development of the Sub-NFMS and Sub-National GHG-Inventory (2021-22). The national definition of forest degradation was developed as a result of detailed literature review and consultative process both at sub-national and national level. The forest degradation is defined as "Human induced long-term losses within forest persisting of at least four years or more due to changes in canopy cover i.e., open (11-30%), sparse (31-50%), medium (51-70%), dense (>70%) resulting in reduction in forest carbon stock and not qualifying as deforestation".

1.3.1.4. Methodology for assessment of Forest Degradation

Methodology for assessment of the forest degradation was developed during the current assignment Sub-NFMS and the Sub-National GHG-Inventory. The methodology is developed keeping in view the national definition of forest degradation. The methodology is based on Spectral Mixture Analysis (SMA), piloted for the first time in Pakistan. The SMA is a technique for estimating the proportion of each pixel that is covered by a series of known cover types. The SMA model decomposes proportional cover based on the reflectance of 'end-members' or pixels containing 100% of the land cover types of interest. Both the SMA and time series analysis are combined to detect forest degradation.

1.3.1.5. Activity Data

The data on the magnitude of human activities resulting in emissions or removals taking place during a given period of time (UN-REDD, 2013; MoCC, 2020).

1.3.1.6. Emission Factors

Emission factors for deforestation represent average net carbon dioxide (CO_2) emissions per hectare of land when forest land has been converted to non-forest land (MoCC 2020). Emission factors for forest degradation represent average net carbon dioxide (CO_2) emissions per hectare of land when a forest (remaining forest) converts from higher canopy cover class to a lower canopy class. For example, in the case of Pakistan when forest canopy cover coverts;

1. From Dense to Medium, Dense to Sparse or Dense to Open;
2. From Medium to Sparse, Medium to Open or
3. From Sparse to Open

1.3.1.7. Forest Stratification

The national forest stratification agreed during the NFMS process was adopted with slight adjustment to the Sub-National level. Moreover, the forest stratification (forest types) map/ boundaries were also reviewed and adjusted (Table 1).

Table 1: National Forest type stratification with adjustments

Climate Zone	**Ecological Zone**		**Adjustments made during the Sub-NFMS process**
	Main Ecological Zone/ Forest Type	**Sub-Ecological Zone/ Forest Type**	
1. Tropical	1.1 Littoral and swamp forest	1.1.1 Mangroves	
	1.2 Tropical dry deciduous		
	1.3 Tropical thorn forest		

	1.4 Riverain forests		
2. Sub-Tropical	2.1 Sub-tropical broad-leaved evergreen forests	2.1.1 Montane sub-tropical scrub Forests	Combined as scrub forests
		2.1.2 Sub-tropical broad-leaved forests	
	2.2 Sub-tropical pine forests		
3.Temperate	3.1 Moist Temperate Forests		
	3.2 Dry Temperate Forests	3.2.1 Montane Dry Temperate Coniferous Forests	Combined Dry Temperate Coniferous, Dry Temperate Broad-leaved Forests and Northern Dry Scrub Forests as Dry Temperate Forests
		3.2.2 Dry temperate Juniper and Chilgoza Forests	
		3.2.3 Dry Temperate Broad-leaved Forests	
		3.2.4 Northern Dry Scrub	
4. Alpine	4.1 Sub-Alpine Forests		
	4.2 Alpine Scrub		
5. Plantation	5.1 Linear Plantations	5.1.1 Road side plantations	
		5.1.2 Railway side plantations	
		5.1.3 Canal side plantations	
	5.2 Irrigated Plantations		

1.3.2. Field and Satellite Based Inventories

For Satellite Based Inventories Landsat-8 imageries were acquired for the reference years 2016 and 2020. A total of 130 Landsat-8 images (65 for reference year 2016 & 65 for 2020) were downloaded from the USGS Earth Explorer web portal using https://earthexplorer.usgs.gov. The forest stratification maps developed during the NFMS/ FREL 2020 were updated and adopted.

For forest inventory the national protocols were reviewed and updated keeping in view the sub-national level context. Number and location of old survey plots were compiled from the NFMS/ FREL reports 2020 and Provincial Carbon Stock Assessment reports of KP, GB and Punjab. The total national level calculated number of sample plots was 2012 (404 clusters) out of which a total of 1526 plots (326 clusters) were surveyed. In AJK the total calculated sample plots were 244 (49 clusters) out which 191 plots (43 clusters) were surveyed. Details of the methodologies adopted for the SLSM and Forest inventories are explained in the following sections.

2. ESTIMATION OF FOREST CARBON STOCK AND EMISSIONS

2.1. Area Covered

According to the National Forest Reference Emission Level of Pakistan (2020), the total area of AJ&K is 13,297 km^2. The current GHG-Inventory report covers the same area.

2.2. Carbon Pools and Gases

The National FREL Report of Pakistan (2020) has covered only CO_2 which is the major GHG emitted from deforestation and forest degradation. The current GHG-Inventory also covers only CO_2 as estimates of other GHG gases are not available at the moment. The current report includes all the five carbon pools for the total carbon stock; Above Ground Biomass; Below Ground Biomass; Deadwood; Litter and Soil Organic Carbon. However, the SOC was excluded from the Emission/ Removal Factors for deforestation, forest degradation and enhancement due to the reason that changes in SOC over the reporting period of four years are insignificant. As per IPCC guidelines the recommended period for assessment of SOC is more than 20 years (IPCC, 2006).

2.3. Activities Covered

The National FREL of Pakistan has covered only deforestation. However, there is an improvement in the current assessment as it covers deforestation, forest degradation and enhancement of forest carbon stocks. According to the national definition of forest (2017) a forest is "A minimum area of land of 0.5 ha with a tree crown cover of more than 10 % comprising trees with the potential to reach a minimum height of 2 meters. This will also include existing irrigated plantations as well as areas that have already been defined as forests in respective legal documents and expected to meet the required thresholds as defined in the national forest definition of Pakistan" (MoCC, 2020). Deforestation refers to "the direct human induced conversion of forest to non-forest (UNFCCC) or the permanent reduction of the tree canopy cover below the minimum 10% threshold (FAO, 2015) as provided in the National FREL of Pakistan (2020). On the other hand, Forest Degradation refers to "Human induced long-term losses within forest persisting of at least four years or more due to changes in canopy cover i.e., open (11-30%), sparse (31-50%), medium (51-70%), dense (>70%) resulting in reduction in forest carbon stock and not qualifying as deforestation" (MoCC, 2021).

2.4. Consistency with National GHG Inventory

In the context of national greenhouse gas inventories, it is mandatory for Non-Annex-I countries to report the CO_2, CH_4 (Methane) and N_2O (Nitrous oxide) emissions. Carbon dioxide must always be included in REDD+ accounting. The CH_4 emissions are normally emitted from the forests growing in wet organic soils. Conversion of these forests through drainage is not an acceptable practice in scope of REDD+. Nitrous oxide emissions take place when biomass is burned, fertilizer is applied or nitrogen fixing trees are planted in the forest, but these activities except fire are rare in Pakistan. Incidences of forest fire have increased in the recent years but there is no data on the quantum of forest degradation caused by forest fire. However, future carbon stock assessments can take into account the emissions caused by forest fire.

3. DATA, METHODOLOGY AND PROCEDURE

3.1. Mapping of Activity Data for Deforestation

Activity data refers to the data on the magnitude of human activities resulting in emissions or removals taking place during a given period of time (UNREDD, 2013). The current report covers activity data on deforestation, forest degradation and carbon stock enhancement. The methodology used for generation of activity data is given as follows.

Supervised machine learning algorithms were used for the Land cover change analysis. Free and Open Source Softwares and imagery were used to achieve the objective. Collect earth was employed to visually interpret the systematic sample plots generated. ROIs were generated from these interpreted plots and training sets were defined. A specific algorithm was used to classify the images to extract the LULC of reference years 2016 and 2020. Post processing was conducted for the noise removal. Accuracy assessment and change maps were developed for the national as well as sub-national level. Following main steps (as recommended under the NFMS, 2020 and FRL/ FREL, 2020) were adopted.

Process 1: Satellite Imagery Acquisition and Processing

Activity data mapping was based on the LULC classification using Landsat imagery 8 for the reference years of 2016 and 2020. Atmospherically corrected and cloud free (less than 10%), Landsat-8 L2SP (Collection 2 level 2 and Tier 1 Science Product) images were downloaded from the from USGS Earth Explorer web portal using https://earthexplorer.usgs.gov. Total, 130 Landsat-8 images (65 for reference year 2016 & 65 for 2020) were downloaded. Landsat-8 OLI image bands (2, 3, 4, 5, 6, 7) were stacked using QGIS, Open-Source software, to generate composites (natural color, VNIR, SWIR etc.) (Table 2). Province wise mosaics were developed in QGIS for using in classification (Table 3).

Table 2: Details of the Landsat-8 images downloaded for one Year

Path	Rows										Total
	34	35	36	37	38	39	40	41	42	43	
147		1	1								2
148		1	1		1						3
149	1	1	1	1	1	1	1				7
150	1	1	1	1	1	1	1	1	1	1	10
151	1	1	1	1	1	1	1	1	1	1	10
152		1	1	1	1	1	1	1	1	1	9
153					1	1	1	1	1	1	6
154					1	1	1	1	1	1	6
155						1	1	1	1	1	5
156						1	1	1	1	1	5
157						1	1				2
Total	3	6	6	4	7	9	9	7	7	7	65

Table 3: Province wise Landsat-8 images processed for Classification

Province	Images for 2016	Images for 2020
AJ&K	4	4
Balochistan	33	33
Gilgit Baltistan	12	12
Khyber Pakhtunkhwa	13	13
Punjab	17	17
Sindh	14	14

Process 2: Systematic Sampling Design and LULC Interpretation

Systematic sampling grids were generated to cover the territory of the Islamic Republic of Pakistan for the sampling for IPCC Land Use classes to be used for preliminary wall-to-wall land use map preparation and forest inventory design. The systematic grids and the sample plots were created using Free and Open-Source Data and Open-Source Tools as part of the desktop-based Satellite Land Monitoring System (SLMS) workflow for the implementation of the Sub-NFMS and conducting the Sub-National GHG-Inventory.

Systematic 10’x10’ or 5’x5’ sample grids were generated to collect the training and validation samples for classification. Visually interpretation for IPCC Land Use Classes (Forest, Cropland, Grassland, Wetland, Settlement, Other land) was done using very high-resolution (VHR) satellite imagery from google earth, False color composites of Landsat 8 and Sentinel 2 and their time series NDVI analysis available in FAO’s OpenForis Collect Earth tool. For Forest plots, sub-plots with tree cover were counted to estimate tree cover in the plot. Observable disturbances in the plot were also interpreted in the VHR images, which mainly include: Logging, Fire, Grazing, Landslide, Tree Plantation, Shifting Cultivation, Construction and others. Total 3,096 visual squared plots with 50x50-meter dimensions were sampled and visually interpreted to get better representation for all the major land use and cover types.

Denser sampling grids were applied for the smaller provinces, AJK to ensure a sufficient number of plots over all the main land use and cover categories (Table 4). Because of its large area, Balochistan province was sampled with the lowest density. Five GIS analysts/ operators were involved in the original interpretation process for different years of assessment, and interpretation results were cross-checked by two GIS experts as well as the forestry experts in the team. All the conflicting observations between the different years were harmonized by supervisors.

Table 4: Province wise number of interpreted plots and plots density

Province Name	10x10 Interpreted Plots	5x5 Interpreted Plots	2.5x2.5 Interpreted Plots	Manually added plots	Total interpreted plots
AJ&K	48	194		55	249
Balochistan	1138			762	1900
Gilgit Baltistan	358			-	358
Khyber Pakhtunkhwa	246			184	430
Punjab	701			405	1106
Sindh	459			12	471
Total	**3096**			**1418**	**514**

To increase the samples of those classes that have low number of sample than others, manual training samples from the systematic grids were added to get better representation for all the major land use and cover types. In addition, to improve the classification results, a set of manual training samples from the systematic grids were added where misclassification was observed to forcefully classify as desired class. About 1,418 samples were also included from denser grids to get the better classification results.

Process 3: Designing Sample Set for Image Training

Satellite image classification was carried out using the Google Earth Engine (GEE) Plugin in QGIS. Region of Interest (ROI) polygons were generated using the interpreted plots as ‘seeds’ using region growing algorithm. The minimum area of ROI was set 2 pixels whereas maximum area was 10 pixels to generate the ROIs. These ROIs basically delimited the spectral signature information against each sample using the SCP Plugin. A representative training set sample with regions of interest (ROI) has been selected by the operators for training image pixels for LULC classification. 70% of the generated ROIs were used as training sample and 30% for the accuracy assessments.

Process 4: Image Classification

Random forest (RF) algorithm was adopted for image classification. The GEE plugin in QGIS was used to carry out the classification process iteratively. The preliminary classification result showed a number of obvious errors, partly due to the lack of training samples in some land cover classes. To address this problem manual training samples were added for the classes (Forest, Crop, Water and settlements) because these classes had a low number of training samples in the interpretation of 10’x10’ grids. The issue of misclassified shadow pixels as forest or water in mountainous region was addressed by adding a new class “Shadow”. The “Shadow” class was then merged with the relevant cover class after verification from the VHR images. Moreover, manual training samples were added at locations where misclassifications were observed to forcefully classify as the desired class. Few training samples which seemed problematic were deleted to get the better classification results. As the systematic 10’x10’ grids were interpreted using Google Earth Imagery and Landsat 7 and 8 and there was the possibility of incorrect interpretation compared to the downloaded images. Each sample was carefully checked by visualizing with different band combinations and spectral signature and deleted the few problematic samples. The class of the few training samples was changed (grasses to other-land and vice versa) to the appropriate class after visualizing the satellite image with different band combinations and spectral response.

Process 5: Post Classification Processing

Post classification processing was applied to remove noise such as ‘salt and pepper’ effects of individual classified pixels and to rectify the misclassification. This was done by “sieving” isolated pixels and replacing them with the classification of surrounding majority class pixels. The threshold for sieving was set to two pixels for one-time Land Use Land cover assessments. The classification results were also compared to historical LULCs; 1). by sharing the GIS data with the concerned GIS experts and focal points of provincial forest departments and getting their input, and; 2). by using Sentinel data as reference for the improvement in accuracy. In addition, feedback from provincial forest departments was obtained during validation consultations using field inventory data and experts’ ground knowledge. Based on this information, misclassifications in the land use and land cover classification maps were identified and corrected manually. For the deforestation map, a minimum 5-pixel threshold was applied and the minimum mapping unit for the deforestation and enhancement was defined as 0.5 ha.

Process 6: Accuracy Assessment and Area Estimation

Accuracy assessment and area estimation of the LULC map classes were conducted using the sample of reference observations of the study area. The basic assumption is that the mapped areas of land cover are biased because of image classification errors, which are identified by comparing the map to a sample of reference observations. 30% random samples were selected from all samples of the reference study areas to measure the accuracy of the classified images for both years (2016 and 2020). The SCP post-processing tool “Accuracy” was used to obtain the result and generate the standard error matrix for LULC analysis. The area estimation of each IPCC class was generated using the classification report tool. These areas can be biased and may not correctly represent the true land cover due to classification errors. In order to adjust these areas, the standard guidelines of REDD+ were followed using referenced samples, that represent accurate estimation of the cover areas of each class. The forest areas of each province were measured by keeping in mind the standard definition of the forest and were further validated with the support of inventory data and feedback from the representatives of provincial forest departments.

Process 7: Land Use Change Assessment

Deforestation activity data generation is based on the visual plots interpreted for the LULC statistics and analyzed with GIS raster analysis operations. A hotspot layer, indicating the potential locations for deforestation, was produced in order to calculate statistics regarding changes from forest to other land use categories.

For the accuracy assessment and change matrix, systematic interpreted plots (over 3,096 plots) and some additional randomly sampled visual interpretation plots (1,418 plots) were investigated. The deforestation area proportions (percentages) by forest types were derived by using the hotspot maps.

For accuracy assessment and permanence check, the final maps were interpreted and crosschecked with the support of experienced foresters in the WWF-Pakistan team and feedback from the representatives of concerned provincial forest departments. Pixel based change detection was conducted using change matrix with spatial distribution. Sieve tool with 5 pixels was applied on the deforestation raster to extract the rate of deforestation and enhancement at the national as well as sub-national level.

3.2. Mapping of Activity Data for Forest Degradation

The methodology for mapping of activity data on forest degradation is based on the Spectral Mixture Analysis (SMA) and has been piloted for the first time in Pakistan. The Spectral Mixture Analysis (SMA) is a technique for estimating the proportion of each pixel that is covered by a series of known cover types. In other words, it seeks to determine the likely composition of each image pixel. The SMA model decomposes proportional cover based on reflectance of 'end-members' or pixels containing 100% of the land cover types of interest. Both the SMA and time series analysis are combined for detecting forest degradation.

3.3. Mapping of Activity Data for Enhancement of Carbon Stock

Enhancement of carbon stock includes increase in forest area through afforestation and reforestation or increasing the density of forest cover so that it changes from a lower density class to a higher density class. Increase in forest area through mapping of plantations raised in provinces was assessed using the following methodology.

Satellite images taken on the earth's surface are analyzed to identify the spatial and temporal changes that have occurred naturally or manmade. Real-time prediction of change provides an understanding related to the land cover. Province wise Pixel based change analysis of Land use land covers of 2016 and 2020, using the machine learning algorithm Random Forest (RF) and the GEE Plugin QGIS software environment has been done to map the Deforestation and Enhancement. Deforestation and enhancement areas were computed and mapped using a sieve of five Landsat-8 pixels, meaning that deforestation/enhancement mapped with less than five pixels was considered noise and merged into the adjacent class. According to the guidance provided by the National REDD+ Project officials and REDD+ guidelines, the minimum mapping unit for deforestation and enhancement was predefined as 0.5 ha.

3.4. Emission and Removal Factors for Deforestation and Enhancement

Emission Factors for deforestation were developed by converting the carbon stock density value (C ton/ha) of each forest type to CO_2 equivalent using an expansion factor of 3.67. Carbon stock values for different forest types were determined using the forest inventory data at sample plot level collected during the current assessment. The carbon density value included aboveground biomass of trees and shrubs, belowground biomass, dead wood, litter and soil organic carbon. However, the EFs/ RFs did not include the SOC. In case of Pakistan, data on non-forest land uses is not available. The emission factors were developed on the basis of the difference in the amount of carbon in carbon pools of the forest and non-forest land uses excluding soil organic carbon. This was mainly due to the reason that accumulation of soil organic carbon takes considerably long time and there may not be a significant difference in the soil organic carbon between forest and non-forest land uses especially during the reporting period of four years (2016-2020). Moreover, changes in soil organic carbon (SOC) largely depend on the type of land management and could be accounted over a period of 20 years in scope of the GHG-I accounting (IPCC, 2006; MoCC, 2020). Due to the same reason the FREL/ FRL Submission 2020 also did not account for the soil organic carbon. Regarding conversion of biomass to carbon the default IPCC fraction (0.47) was applied.

3.4.1. Sampling Design

The sampling scheme was designed using the stratified two-phase sampling approach with integration of the SLMS process. During the first phase a systematic grid of 10’x10’ was generated which was used for visual interpretation of land use and forest cover analysis. During the second phase 10’x10’ grid was adjusted to 5’x5’/2.5’x2.5’/1.25’x1.25 according to the provincial level forest mask to determine the number of sample plots and accessibility criteria. The stratification was done on the basis of forest types using the forest mask (2012) and the forest type boundaries developed during the pilot NFI 2018. The two-phase sampling process, the number of sample plots calculated and stats applied during the sample plots calculations are given in Table 5 below and Figure 1. The sample design included the following steps.

- Systematic generation of 10’ x 10’ grids (at national level)
- Adjustment of grids to provinces and forest types (5’ x 5’, 2.5’ x 2.5’, 1.5’ x 1.5’). The 10’ x 10’ grids, when did not fit according to the number of sample plots, the forest types then the girds were adjusted accordingly to (5’ x 5’, 2.5’ x 2.5’, 1.5’ x 1.5’).
- Calculation of province and forest type wise number of sample plots on the basis of mean biomass and standard deviation using the Win Rock Sample Plot Calculator. The mean biomass and standard deviations were taken from the NFMS data 2018. Forest types were used as forest strata and the province and forest type wise areas were taken from the 2012 forest mask and forest statistics.
- Plotting of sample plots on maps (province wise and forest wise). Used the 2012 forest mask (cover map) for laying out and mapping of the sample plots.
- Repeating previous inventory plots. The sample plots of 2018 forest inventory as well as the provincial forest inventories in KP, GB and Punjab were repeated.
- Development of province wise, district wise and cluster wise maps of sample plots.

Table 5: Province wise number of sample plots

Forest Type/Strata	KP		GB		AJK		Punjab		Sindh		Balochistan		Total	
	Plot	Cluster	Plot	Cluster	Plot	Cluster	Plot	Cluster	Plot	Cluster	Plot	Cluster	Plot	Cluster
Sub-Alpine	15	3	55	11	15	3	0	0	0	0	0	0	85	17
Dry Temperate	91	18	410	82	20	4	0	0	0	0	200	40	721	145
Moist Temperate	225	45	0	0	150	30	15	3	0	0	0	0	390	78

Pine	100	20	0	0	35	7	135	27	0	0	0	0	270	54
Scrub	15	3	0	0	25	5	85	17	15	3	15	3	155	31
Thorn	15	3	0	0	0	0	20	4	55	11	15	3	105	21
Riverine	0	0	0	0	0	0	15	3	60	12	0	0	75	15
Mangrove	0	0	0	0	0	0	0	0	60	12	15	3	75	15
Irrigated Plantations	0	0	0	0	0	0	100	20	50	10	0	0	150	30
Total	461	92	465	93	245	49	370	74	240	48	245	49	**2,026**	**406**

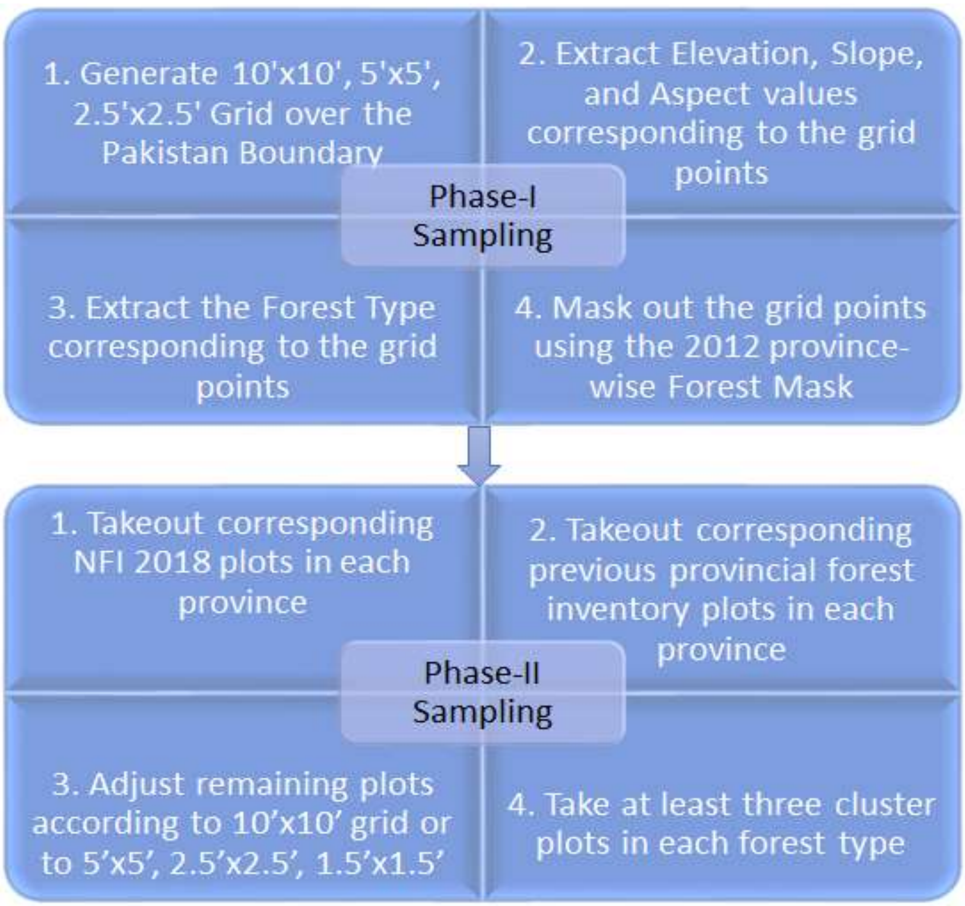

Figure 1: Stratified two-phase sampling process with integration of the SLMS process

Cluster sample design as adopted during the pilot National Forest Inventory, 2018 was followed to have consistency with previous inventory (MoCC, 2020). A cluster sample plot comprises of five subunits or sub-plots; a Primary Sub Unit (PSU) situated at the center of the cluster and four Secondary Sub Units (SSUs) located at the four corners 200 meters apart from each other (Figure 3). Each sub-unit or sub-plot comprised of three concentric circular plots; 1). A plot with a radius of 17.84 meters (~1000 m^2) for measuring all living trees and standing deadwood stems with DBH1 above 5 cm; 2). A sub-plot with a radius of 5.64 meters (~100 m^2) for counting seedlings and measurement of shrubs, and; 3). A sub-plot with a radius of 0.56 meter (~1 m^2) for measuring and taking above-ground non-tree, litter and soil samples (Figure 3). Complete workflow of the forest inventory is given in Figure 2.

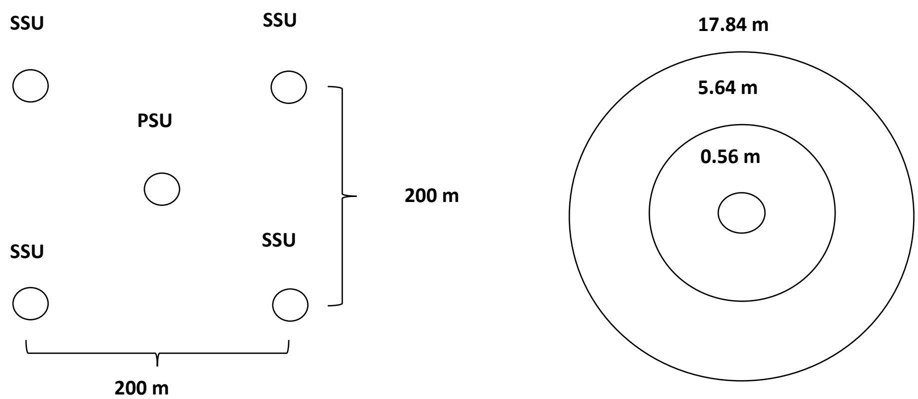

Figure 2: Forest Inventory Workflow (Source: adopted from NFMS-MRV Report, MoCC, 2020)

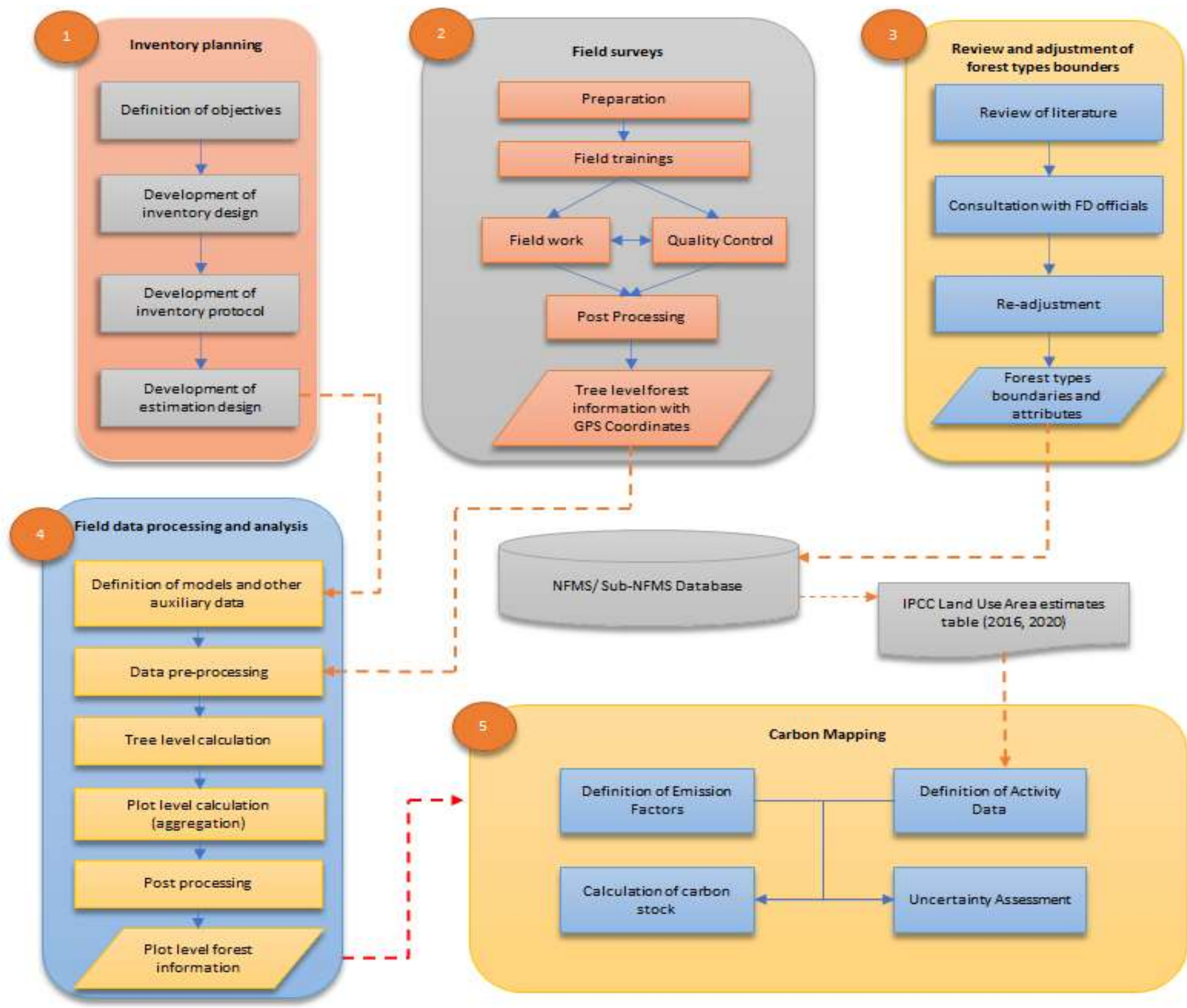

Figure 3: Clustered primary and secondary sample units (plots). Source: NFMS – MRV Report, 2020

3.4.2. National Forest Inventory Protocol

The National Forest Inventory Protocol were mainly adopted from the National Forest Inventory Manual developed during the NFMS development in 2018-2020 with minor adjustments according the new situation. The protocol mainly consisted of; 1) formation of field teams (team leader and members, and their duties); 2) Proper field measurements and collection of samples during the field work (general information of the plot i.e., coordinates, elevation, aspect, slope, disturbance etc., measurement of tally trees, measurement of sample trees, measurement of dead wood, litter, shrubs and regeneration, and soil, and taking samples for lab test); 4) Quality Control and Quality Assurance during the forest inventory as well as the post inventory data entry, cleansing and processing phases.

All carbon pools i.e., aboveground biomass (trees and shrubs), belowground biomass, dead wood, litter and soil organic carbon were measured during the current assignment. Following protocols for measurements were considered during the forest inventory (Revised Forest inventory manual 2022 is given as Annex-8) (provided as separate file).

- Cluster Information (Primary Sampling Unit)
    - Time log (starting time and reaching time)
    - Coordinates of waypoints
    - GPS coordinates of PSU location
- Plot information and Land Use
    - Measurement Time Log
    - GPS Coordinates
    - Terrain Parameters (Slope in %, Aspect, Erosion, Main site type (mineral soil, peat lands, wetlands))
    - Land Use type (forest land (and type), cropland, grassland, settlements, wetlands, other land)
    - Canopy cover (<10%, 10-30%, 31-50%, 51-70%, and >70%)
    - Disturbances
    - Land Use and Land Use Change (Deforestation, Forest Degradation and causes)
- Measurement of tally trees
    - All trees with DBH-1 above 5 cm are measured from the sample plots with radius of 17.84 m
    - Species and DBH-1 (at 1.3 meters). In case of anomaly at 1.3 m the DBH was measured slightly above that point. In case of forked tree below DBH, two trees were considered.
    - Broken top or not. Broken top trees were not selected as sample trees.
- Measurement of sample trees
    - Sample trees were selected from all measured alive trees by selecting every 5th tree starting from tree no. 1.
    - If the selected tree had a broken top or had some anomaly at the breast height, it was not selected as sample tree. In that case the next tree in order was selected as sample tree, however, the next sample tree was selected based on the same order.
    - The sample trees were measured for second DBH with breast height at 1.37 meters, top height, bole height, and in case of leaning trees also base length for both top height and bole height.
- Dead wood measurement
    - Species Name
    - Category (Standing Dead Wood, Down Dead Wood and Stump)
    - Standing Dead Wood:
        - All the standing dead trees with DBH1 measured at 1.3 m height greater than 5 cm were enumerated within the full 17.84 m plot.
        - DBH1, top height and decomposition state were recorded for all the standing dead trees.
        - The specific decomposition stage classes for standing dead wood are:
            - 1) Tree with branches and twigs and resembles a live tree (except for leaves);
            - 2) Tree with no twig, but with persistent small and large branches;
            - 3) Tree with large branches only;
            - 4) Bole (trunk) only, no branches
    - Downed Dead Wood:
        - Downed branches and stems of trees and brush with minimum DBH above 5 cm, which were fallen and lied on or above the ground were measured from the 17.84 m.
        - Only the proportions of dead wood stems and their fragments lying inside were measured.
        - The measurements included the length (m) inside the plot and diameters (cm) at the two ends of the wood or fragment particle.

- Stumps: All the stumps with diameter above 5 cm were enumerated within the full 17.84 m plot.
    - The stump diameter was measured in two diagonal directions, its lowest and highest heights with a measuring tape from the level of seeding point.
    - For dead wood following decomposition levels were assessed;
        - 1) Sound (blade does not sink or is bounced off).
        - 2) Intermediate (blade partly sinks into the piece of wood or there has been some wood loss).
        - 3) Rotten (blade sinks well into the piece, there is extensive wood loss and the piece is crumbly).
- DBH/Diameter 1 (x.x cm): The first end diameter measurement for downed deadwood, stump diameter or DBH at 1.3 meters for standing trees.
- Diameter 2 (x.x cm): The second end diameter measurement for downed deadwood or stump.
- Tree height / length (x.x m): Tree height or particle length measured in meters
- Standing tree, base length (x.x m): The standing dead tree base length is only measured for heavily leaning sample trees. Tree base length is the distance on the ground from the base of the tree to the top of the trunk.
- Standing tree broken top (1/0): All the standing dead trees were marked as broken top or not. 1 was for broken top, and 0 was for normal.

- Measurement of litter and shrubs
    - Shrubs were measured through destructive sampling in the 5.64 m plot. Shrubs were cut, weighed and recorded. The shrubs were then chopped and a certain portion was taken, weighed, packed and labelled as sample for lab testing (for determining oven dry weight.
    - Non-tree biomass Litter, herbs, grasses and soil biomass are extracted from the 0.56 m sub-plots.
    - The litter layer is defined as include all dead organic surface material on top of the mineral soil.
    - All the leaf litter and wood litter less than 5 cm in diameter within the subplot were collected and their fresh weights determined in the field with a weighing balance.
    - The sample weighted on site after excluding the plastic bag weight.
    - A sub-sample for plot was taken, weighed, placed in a zip-locked polythene bag, labelled and then taken to the laboratory to determine the oven dry mass and carbon content.
- Measurements for soil organic carbon
    - Due to time constraint soil samples were collected only from the PSUs in each cluster.
    - For Soil Organic Content collected the soil samples using the auger/ chisel and put it in a clean bucket.
    - Samples from the different depths were placed in separate buckets.
    - Mixed the soil in the bucket thoroughly and took sub-samples, put in a sampling bag.
    - The sample was weighed and labelled with sample ID and fresh weight.
    - For bulk density the soil sample was taken using a cylindrical metal sampler of 5 cm diameter and 5 cm length.
    - The core was driven to the desired depth (0 – 10 cm, 10 – 20 cm and 20 – 30 cm) using a hammer and the soil sample carefully removed to preserve the known soil volume existed in situ using the soil knife.
    - Volume and fresh weight of the soil collected in the core from each depth were recorded.
    - The soil sample was then transferred into a clean sampling bag without spilling it and label the sample bag clearly.

  - Filled in soil sample information sheet including the details (name of sample collector, address, date, area and location).
  - Packed the samples in clean bags and took to the laboratory for analysis.
- Plot photos
  - Photographs at each PSU and SSU were taken towards the compass direction in North, East, South and West from the plot center.
  - The corresponding Photo number/ID/ file name with other site characteristics were noted in the field sheets.

As recommended in the revised forest inventory manual both hot and cold checks were performed. The hot checks consisted of spot visits by the WWF-Pakistan's provincial coordinators and sometimes the concerned provincial REDD+ focal persons to the inventory sites and checked the data collection procedures in the field. For the cold checks the team visited the forest inventory teams, randomly picked 10% clusters and re-measured the tree parameters and dead wood in the PSUs of the selected clusters. The data was entered in OF Collect entry sheets and the error was assessed using the Power BI software using the formula below:

$$Measurement\ error\ (\%) = \frac{(biomass\ before\ corrections - biomass\ after\ corrections)}{biomass\ after\ corrections} \text{ X } 100$$

3.4.3. Data Storage and Processing

The entire process of data storage and processing consisted of three phases: I) data acquisition, II) data entry, III) data cleansing and IV) data analysis. Measured and/or estimated data was recorded in the field on the field sheets during the NFI (I. Field data acquisition). Duly filled in field sheets were delivered to the office where the recorded values were crosschecked and entered into the OF data management software (II. Data Entry). The software runs several validation rules against the entered data and indicates erroneously entered or missing values. Once the (per cluster) data sets were complete, they were promoted to the data cleansing stage (III. Data Cleansing). Consequently, these were exported to PBI for a systematic data cleansing. In PBI the values were systematically checked again for completeness and plausibility, e.g., value ranges, conspicuous values, etc. Data Storage and Processing report is given as Annex-9 (provided as separate file) (provided as separate file).

Following the data entry and cleansing procedures of NFI field data in OF, the ("analysis ready") data is exported as data tables in MS Excel format (IV: Data Analysis). The data processing workflow is illustrated in Figure 4. The entire workflow can be summarized as under.

- Measurement/estimates values were recorded on field sheets.
- Field sheets data were entered in OpenForis Collect.
- Data was controlled (cross-checks), validated (plausibility) and checked for completeness.
- Complete data sets were promoted to "data cleansing" and exported to PBI.
- In PBI, systematic data cleansing was applied, considering completeness and plausibility.
- Cleansed data was promoted to "data analysis" and exported to PBI for analysis.
- Data issues (i.e., outliers, etc.) observed during data analysis result in data sets were demoted to "data cleansing".

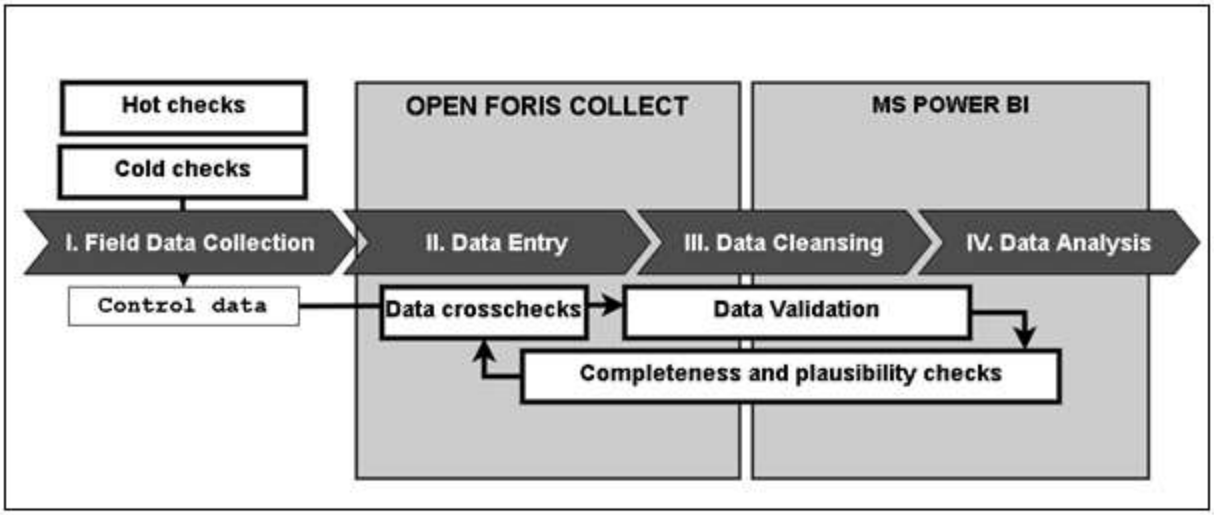

Figure 4:Data storage and processing workflow

3.4.4. Diameter-Height model development

Initially the Diameter-Height models were developed for species, genera or species groups having more than 30 height measurements. Species or genera having less than 30 height measurements were grouped as other coniferous species and other broadleaved species (for each province). These models were developed using excel spreadsheets based on R values (Table 6). The initially developed models (representing the DBH-H relationships per species, genera or species group) were then adjusted and used to determine the missing tree-height values for each species. For the PBI analysis, the performance of available Diameter-Height models was assessed visually (Table 7).

Table 6: Diameter-Height Models developed during initial stage

Species	Range of DBH (cm)	Range of height (m)	Number of sample trees	Model
Abies pindrow	5-120	3.9-49.5	135	H = 2.5597*(DBH)^0.5929 R^2 = 0.7636
Acacia modesta	5-46	2-11.6	131	H = 3.7547*Ln(DBH) - 3.7217 R^2 = 0.6105
Acacia nilotica	5-57	2.8-25.5	135	H = 0.0023*(DBH)^2 + 0.209 *(DBH) + 3.6328 R^2 = 0.6795
Aesculus indica	9-116.33	4.4-47.2	44	H= 0.0016*(DBH)^2 + 0.2037*(DBH) + 3.2397 R^2 = 0.9094
Cedrus deodara	5-94.5	2-39.4	210	H= 1.1322(DBH)^0.7551 R^2 = 0.7937
Olea ferruginea *Olea europea (cuspidate)*	5-64	2.9-11.9	307	H = -0.001*(DBH)^2 + 0.2077*(DBH) + 2.9166 R^2 = 0.5139
Picea smithiana	5-108.2	2-41.2	149	H = -0.0035x2 + 0.6912x + 0.2213 R^2 = 0.7367

Species	Range of DBH (cm)	Range of height (m)	Number of sample trees	Model
Pinus roxburghii	5-106.5	2-39.6	548	H = -0.0006*(DBH)^2 + 0.3518 *(DBH) + 5.2698 R^2 = 0.7225
Pinus wallichiana	4-134	1.5-44.5	611	H = -0.0015*(DBH)^2 + 0.504*(DBH) + 2.3565 R^2 = 0.8037
Quercus dilatata	5-84	1-30-3	91	H = 0.0008x^2 + 0.2511x + 2.9845 R^2 = 0.7541
Quercus ilex	5-51	3-21	197	H = 0.002*(DBH)^2 + 0.1873*(DBH) + 2.5811 R^2 = 0.5725
Quercus incana	5-45	2-27	241	H = 0.0099*(DBH)^2 - 0.1211 *(DBH) + 4.8764 R^2 = 0.5789
Dalbergia sissoo	5-50	2.7-30.8	70	H = 0.0038*(DBH)^2 + 0.2994*(DBH) + 3.5519 R^2 = 0.6875
Other (broadleaved) Species AJK	5-20	4.3-21.2	34	H = 0.0151*(DBH)^2 + 0.5747*(DBH) + 1.4868 R^2 = 0.8244

Table 7: Finally selected Diameter-Height Models with descriptive statistics

Tree Species	Model	n Tree H	RMSE	RMSE (%)
Pinus roxburghii	'-0.0006*'tree'[dbh1]^2 + 0.3518 *'tree'[dbh1] + 5.2698	554	4.164	0.633
Quercus dilatata	0.0008*'tree'[dbh1]^2 + 0.2511*'tree'[dbh1] + 2.9845	88	2.396	0.536
Olea ferruginea	'-0.001*'tree'[dbh1]^2 + 0.2077*'tree'[dbh1] + 2.9166	504	1.970	0.898
Pinus wallichiana	'-0.0015*'tree'[dbh1]^2 + 0.504*'tree'[dbh1] + 2.3565)	923	4.544	0.556
Aesculus indica	0.0016*'tree'[dbh1]^2 + 0.2037*'tree'[dbh1] + 3.2397	47	2.658	0.305
Ailanthus altissima	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	15	2.748	0.824
Camellia japonica	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	1	0.165	
Diospyros lotus	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	12	1.255	1.137
Ficus carica	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	16	1.932	0.949
Grewia optiva	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	23	2.567	1.070
Juglans regia	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	24	2.513	0.636
Prunus domestica	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	6	2.413	0.887

Prunus persica	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	1	2.500	
Pyrus pashia	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	12	3.335	1.357
Robinia pseudoacacia	'-0.0018*'tree'[dbh1]^2+0.3569*'tree'[dbh1]+2.4247	1	1.836	
Acacia nilotica	0.0023*'tree'[dbh1]^2 + 0.209 *'tree'[dbh1] + 3.6328	162	3.084	0.797
Dalbergia sissoo	'-0.0038*'tree'[dbh1]^2 + 0.2994*'tree'[dbh1] + 3.5519	84	5.640	1.005
Eucalyptus camaldulensis	'-0.0051*'tree'[dbh1]^2 + 0.7603*'tree'[dbh1] - 0.6817	299	3.774	0.549
Quercus incana	0.0099*'tree'[dbh1]^2-0.1211*'tree'[dbh1]+4.8764	350	5.151	1.599
Cedrus deodara	1.1322*'tree'[dbh1]^0.7551)	299	4.395	0.595
Pistacia spp.	1.3+1.7688957*'tree'[dbh1]^0.5153645	9	2.641	4.402
Platanus orientalis	1.3+1.7688957*'tree'[dbh1]^0.5153645	1	0.284	
Picea smithiana	1.3+31.70924806*(1-exp((-0.03712483*'tree'[dbh1])))^1.46781861	189	5.212	0.543
Pinus wallichiana	1.3+56.25256*(exp(-19.55755*('tree'[dbh1])^-1))	923	4.544	0.556
Betula utilis	1.3+8.244514*exp(-7.752015*'tree'[dbh1]^-1)	15	5.341	1.040
Olea europaea	1.3+8.244514*exp(-7.752015*'tree'[dbh1]^-1)	5	1.534	2.036
Prunus Spp	1.3+8.244514*exp(-7.752015*'tree'[dbh1]^-1)	10	1.282	1.356
Salix tetrasperma	1.3+8.244514*exp(-7.752015*'tree'[dbh1]^-1)	25	3.532	0.932
Abies pindrow	2.5597*'tree'[dbh1]^0.5929)	143	6.042	0.642
Populus ciliata	'-6.9198+8.4004*LN('tree'[dbh1])	14	7.801	2.454

3.4.5. Allometric models for Above-Ground Tree Biomass estimation

Above-ground biomass models are available for 63% of all observed tree species. For coniferous species, which did not have any national level models, the generic coniferous species allometric model used by Ali et al., 2017 was applied. For the remaining species the allometric equation developed by Chave et al. (2005) was used. Table 8 presents the allometric models applied for Above Ground Biomass estimation in AJK.

Table 8: Allometric models applied for Above Ground Biomass estimation

Sr. No	***Species Type***	**Allometric Equation**	**Reference/ Province**
1	*Abies pindrow*	M=0.0954*(DBH^2*H) ^0.8114	Ali et al. 2017 (GB)
2	*Abies pindrow*	M= 0.0495(D^2H)^0.8935	Ali 2020 (KP)

3	*Acacia nilotica*	M= 0.0493(D^2H)^0.9728	Ali 2020 (KP)
4	*Accacia nilotica*	M= 0.0569(D^2*H)^0.9745	Ali 2019 (Sindh & Punjab)
5	*Cedrus Deodara*	M=0.1779*(DBH^2*H) ^0.8103	Ali et al. 2017 (GB)
6	*Cedrus deodara*	M= 0.0458(D^2H)^0.92	Ali 2020 (KP)
7	*General (Coniferous)*	M=0.1645*(WD*DBH^2*H) ^0.8586	Ali et al. 2017 (GB)
8	*Olea ferruginea*	M= 7.8863+0.0556(D^2H)	Ali 2019 (Sindh & Punjab)
9	*Olea ferruginea*	M= 7.8863+0.0556(D^2H)	Ali 2020 (KP)
10	*Other Mix*	M=0.0673*(WD*DBH^2*H) ^0.976	RFEL/NFMS, 2020
11	*Other species*	M=Exp (-2.187+0.916*ln (WD*D^2*H))	RFEL/NFMS, 2020
12	*Picea smithiana*	M= 0.0821(D^2H)^0.8363	Ali 2020 (KP)
13	*Picea smithina*	M=0.0843*(DBH^2*H) ^0.8472	Ali et al. 2017 (GB)
14	*Pinus roxburghii*	M=0.1645*(0.327*DBH^2*H) ^0.8586	RFEL/NFMS, 2020
15	*Pinus roxburghii*	M= 0.0224(D^2H)^0.9767	Ali 2020 (KP)
16	*Pinus wallichiana*	M=0.0631*(DBH^2*H) ^0.8798	Ali et al. 2017 (GB)
17	*Pinus wallichiana*	M= 0.0594(D^2*H)^0.881	Ali 2020 (KP)
18	*Quercus ilex*	M=0.8277*(DBH^2*H) ^0.6655	Ali et al. 2017 (GB)
19	*Quercus ilex*	M= 0.0795(D^2H)^ 0.9688	Ali 2020 (KP)
20	*Robinea pseudoacacia*	M= 0.2586(D^2H)^0.7786	Ali 2020 (KP)

3.5. Emission Factors for Forest Degradation

Emission factors for forest degradation were developed by determining the carbon density values (C t/ha) of different forest strata and the difference between these values when one forest stratum is degraded into a lower stratum due to logging or other anthropogenic activities. The following strata were used:

- open forest (canopy cover 11-30%)
- sparse forest (canopy cover 31-50%)
- medium (canopy cover 51-70%)
- dense (canopy cover >70%)

3.6. Reference Period

The reference period for the current MRV is 2016-2020. Activity data for deforestation and forest degradation was generated for 2012-2016 and 2016-2020. Data for development of Emission Factors was collected during 2021-2022.

3.7. Emissions Calculation

The sample plot-based emissions assessment process involves a modelling chain with the following critical steps:

- Field measurements of carbon pools and data entries;
- Height modelling for individual trees;
- Allometric biomass modelling of aboveground biomass for individual trees;
- Applying default root-shoot ratios to estimate belowground biomass;
- Laboratory analysis to determine moisture content in shrubs and litter;
- Laboratory Analysis to determine carbon contents in soil samples;
- Aggregation of plot level data;
- Expansion of plot level data to derive values on per ha basis;
- Conversion of carbon density values to CO_2 equivalent

3.8. Emission Calculation from Deforestation

Deforestation refers to the conversion of forest land into another land use category. The emission factors for deforestation represent emissions per hectare of land which has been converted to other land use. Activity data i.e., estimate of area on deforestation is provided by SLMS. Activity data (AD) when multiplied by Emission Factor (EF) gives emissions as given below:

$$Emissions = EF * AD$$

Table 9 indicates the formulas that have been used to derive the emission factors by forest strata. As shown in Table 10 respective default values of carbon densities for land use classes of cropland and grassland were adopted (IPCC, 2006). For wetland, settlement and other land no specific default values were available and were assumed as zero (IPCC, 2006).

Table 9: Formulas used to derive the emission factors for deforestation

	Term	Variable Definition/Formula
Forest converted to non-forest land (cropland, grassland, settlements, wetlands and other land)	A	Forest carbon density, mean AGC+BGC+Deadwood+litter (ton C/ha)
	B	Non-forest land mean carbon density (ton C/ha) (IPCC, default values)
	EF	(A-B) x 3.67
	EF	**Emission factor (ton CO_2-e/ha)**

Table 10: Default values of carbon densities in non-forest land use classes adopted for EFs/RFs of deforestation/ Enhancement

Forest type/ climate zone	Default C densities (C t/ ha)		
	Cropland	Grassland	Wetland/ Settlement/ Other land
Sub-Alpine Forests	2.1	3.1	0
Dry-Temperate Forests	2.1	3.1	0
Dry temperate Juniper and Chilghoza Forests	2.1	2.9	0
Moist-Temperate Forests	2.1	6.4	0
Subtropical Chir Pine Forests	2.1	6.3	0
Subtropical broad leaved (Scrub)	1.8	4.1	0
Tropical Thorn Forests	1.8	4.1	0
Riverine Forests	1.8	4.1	0
Mangrove Forests	1.8	4.1	0
Irrigated Plantation	1.8	4.1	0

Source 1: IPCC, 2006.

3.9. Emission Calculation from Forest Degradation

Emissions of forest degradation were determined by multiplying Emissions factors for degradation with activity data. Activity data for forest degradation was provided by SLMS and emissions factors were developed by calculating the difference of carbon density values for different canopy cover strata within the same forest type.

The following table indicates the formulas that have been used to derive the emission factor for forest degradation.

Table 11: Formulas used to derive the emission factor for forest degradation

	Term	Variable Definition/Formula
Dense Moist Temperate Forest converted to Sparse Moist Temperate Forest	A	Forest carbon density in Dense Moist Temperate Forest, mean AGC+BGC+Dead wood+litter (ton C/ha)
	B	Forest carbon density in Sparse Moist Temperate, mean AGC+BGC+Dead wood+litter (ton C/ha)
	EF	(A-B)x3.67
	EF	**Emission factor (ton CO_2-e/ha)**

3.10. Removal/Sequestration from Enhancement

Removal or sequestration of CO_2 occurs when an area is reforested or afforested or its forest cover is improved resulting in enhancement of carbon stock. Removal Factors are the opposite of Emission Factors of deforestation or forest degradation.

Removal from enhancement were determined by multiplying removal factors for afforestation or reforestation with activity data. Activity data for enhancement was provided by SLMS and removal factors were developed by calculating the difference of carbon density values for different strata and canopy cover classes.

The following table indicates the formulas that have been used to derive the removal factors (RF) for enhancement when i) other land is converted to forest ii) forest degradation is reversed i.e., sparse forest is converted to dense forest. The RFs for enhancement are calculated for the normal age of each forest type. Mean ages of different forest types taken from Ali, 2018; Ali, 2019 and Ali, 2020 are given as Annex-16.

Table 12: Formulas used to derive the removal factors (RF) for enhancement

Enhancement	Term	Variable Definition/Formula
Other land converted to forest	**A**	Forest carbon density, mean AGC+BGC+Deadwood+litter (ton C/ha)
	B	Non-forest land mean carbon density (ton C/ha) (IPCC, default values)
	RF*	(A-B) x 3.67
	RF*	**Removal Factor (ton CO_2-e/ha)**
Sparse Moist Temperate Forest converted to Dense Moist Temperate Forest	A	Forest carbon density in Dense Moist Temperate Forest, mean AGC+BGC+Dead wood+litter (ton C/ha)
	B	Forest carbon density in Sparse Moist Temperate, mean AGC+BGC+Dead wood+litter (ton C/ha)
	RF	(A-B)x3.67
	RF	**Removal Factor (ton CO_2-eq/ha)**

*Note: RF for enhancement covers the normal age of each forest type. Annual removals in each forest type can be derived by dividing the removals by the mean age of each forest type. Mean ages of each forest type are given as Annex-16.

4. RESULTS

4.1. Forest Type Wise Carbon Stock

The total carbon stock in AJK's forests was estimated as 58.37 million tons for 2020. The average carbon density in the forests was estimated as 94.45 t/ha. The highest carbon density was found in moist temperate forest (121 t/ha), followed by dry temperate forests (102 t/ha), subtropical pine (89 t/ha), sub-alpine forest (66 t/ha), subtropical broad-leaved forests (57 t/ha) and dry tropical thorn forest (35 t/ha). Total carbon stocks and carbon densities in different forest types (including soil organic carbon) are shown in Table 13. Carbon pool wise breakup of carbon densities with and without SOC are given as Annex-10.

Table 13: Carbon stocks in different forest types (including soil organic carbon)

	2016			2020		
Forest Type	Area (ha)	C Density (tC/ha)	Carbon Stock (Mt C)	Area (ha)	C Density (tC/ha)	Carbon Stock (Mt C)
Sub-Alpine	4330	66.22	0.29	4355	66.22	0.29
Dry Temperate	19292	101.57	1.96	19323	101.57	1.96
Moist Temperate	251467	120.92	30.41	251692	120.92	30.43
Sub-tropical Pine	190833	89.15	17.01	190944	89.15	17.02
Subtropical broad leaved (Scrub)	150865	57.01	8.60	151694	57.01	8.65
Tropical Thorn	423	35.24	0.01	451	35.24	0.02
Total	**617211**	**94.45**	**58.28**	**618460**	**94.45**	**58.37**

4.2. Emission Factors for Deforestation

Emission factors for different forest types of AJK are given in **Error! Reference source not found.**. Emission f actors for deforestation in each forest type was derived by subtracting the mean carbon density of the respective non-forest land use from the mean carbon density of forest land use and multiplying the value with 3.67 (Table 9). Default values of mean carbon densities of the five non-forest land use classes were taken IPCC, 2006 guidelines. The emission factors for deforestation exclude soil organic carbon due to the reason that changes in SOC occur over a period of more than 20 years. Since emissions factors for different forest types at sub-national scale have high standard errors due to insufficient numbers of sample plots at the subnational level, the national level emission factors developed under this assignment were used. Uncertainties of EFs for deforestation are given in Table 14. Uncertainties of emission factors for deforestation are given as Annex-13.

Table 14: Emission Factors for Deforestation (excluding soil organic carbon)

Forest type	Mean Carbon Density of forest (t C/ha)	SE (%)	Emission Factor (EF) (CO2e t/ha)				
			Forest-Cropland	Forest-Grassland	Forest-wetland	Forest-Settlement	Forest-Other land
Sub-Alpine Forests	39.3	20.6	136.5	132.8	144.2	144.2	144.2
Dry-Temperate Forests	52.3	11.8	184.0	180.3	191.7	191.7	191.7
Dry temperate Juniper and Chilghoza Forests	28.7	23.0	97.4	94.4	105.1	105.1	105.1
Moist-Temperate Forests	69.1	12.2	245.6	229.8	253.3	253.3	253.3
Subtropical Chir Pine Forests	41.2	16.2	143.3	127.9	151.0	151.0	151.0
Subtropical broad leaved (Scrub)	10.1	15.3	30.3	21.9	36.9	36.9	36.9
Tropical Thorn Forests	7.5	25.7	20.7	12.3	27.3	27.3	27.3

4.3. Estimates of Deforestation

The total area of deforestation in AJK during 2016-2020 was determined as 612 ha. The average annual deforestation rate was calculated as 153 ha for the period. The highest deforestation was found in subtropical broad-leaved forest (156 ha) followed by subtropical pine forest (149 ha) and moist temperate forest (124 ha). Detailed deforestation estimates of different forest types are given in Table 15. Forest types maps, and land use land cover change maps of AJK are given as Annex-3, 4, 5 and 6.

Table 15: Estimates of deforestation in different forest types

Forest type	Forest-Cropland (ha)	Forest-Grassland (ha)	Forest-wetland (ha)	Forest-Settlement (ha)	Forest-Other land (ha)	Total deforestation (ha)	%
Sub-Alpine Forests	0.00	51.39	0.00	0.00	27.45	78.84	12.89
Dry-Temperate Forests	0.00	80.73	0.00	0.00	21.60	102.33	16.73
Moist-Temperate Forests	22.41	99.81	1.62	0.54	0.54	124.92	20.42
Subtropical Chir Pine Forests	81.90	65.88	0.00	1.71	0.00	149.49	24.44

Subtropical broad leaved (Scrub)	83.43	65.52	1.62	3.78	1.71	156.06	25.52
Tropical Thorn Forests	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**187.74**	**363.33**	**3.24**	**6.03**	**51.30**	**611.64**	**100.00**

4.4. Estimates of forest degradation and improvement in forest cover density

The total area under forest degradation in AJK during 2016-2020 was estimated as 35,202 ha. The highest degradation was found in moist temperate forests (47%), followed by subtropical pine forest (27%) and subtropical broad-leaved forest (18%). Estimates of forest degradation in different forest types are given in Table 16. Similarly, the total improvement in forest cover density was assessed as 73,686 ha with the highest improvement coming from Moist Temperate Forest (37%) followed by Sub-tropical Pine Forest (32%), and Sub-tropical Broadleaved Forest (27%). Thus, an overall improvement in forest cover densities of 38.483 ha was found in the forests of AJK (Table 16).

Table 16: Estimates of Forest Degradation

Forest Type	Total degradation during 2016-2020 ha)		Total improvement in forest cover density		Net Balance (ha)
	Area (ha)	**%**	**Area (ha)**	**%**	
Sub-Alpine	640	1.82	531	0.72	109
Dry Temperate	2096	5.95	2,595	3.52	-499
Moist Temperate	16602	47.16	27,107	36.79	-10,505
Sub-tropical Pine	9558	27.15	23,697	32.16	-14,140
Subtropical broad leaved (Scrub)	6283	17.85	19,636	26.65	-13,353
Tropical Thorn	23	0.07	120	0.16	-97
Total	**35,202**	**100.00**	**73,686**	100.00	**-38,483**

4.5. Estimates of Enhancement

The total area of forest enhancement due to reforestation and afforestation in AJK during 2016-2020 was estimated as 856 ha. The average annual enhancement rate was calculated as 214 ha for the period. The highest enhancement was found in sub-alpine forest (213 ha) followed by subtropical broad-leaved forest (177 ha) and moist temperate forest (176 ha). Detailed enhancement estimates of different forest types and are given in Table 17.

Table 17: Estimates of Enhancements

Forest type	Cropland-Forest	Grassland-Forest	Wetland-Forest	Settlement-Forest	Otherland-Forest	Total	%
Sub-Alpine Forests	0.00	38.70	0.00	0.00	174.60	213.30	24.93
Dry-Temperate Forests	0.00	58.86	0.00	0.00	89.82	148.68	17.38
Moist-Temperate Forests	26.46	129.06	0.54	0.00	20.16	176.22	20.60

Subtropical Chir Pine Forests	63.09	68.58	3.60	0.54	1.08	136.89	16.00
Subtropical broad leaved (Scrub)	69.39	99.72	6.21	2.07	0.00	177.39	20.73
Tropical Thorn Forests	0.00	1.98	0.00	0.00	1.08	3.06	0.36
Total	**158.94**	**396.90**	**10.35**	**2.61**	**286.74**	**855.54**	**100.00**

4.6. Emissions from Deforestation

The total emissions from deforestation were estimated as 0.08 million tons of CO_2e between 2016 and 2020. The largest share of CO_2 emissions originated from moist temperate (35%), followed by subtropical Chir pine (24%), and dry temperate forest (22%) (Figure 5). Forest type wise detailed emissions estimates are given in Table 16

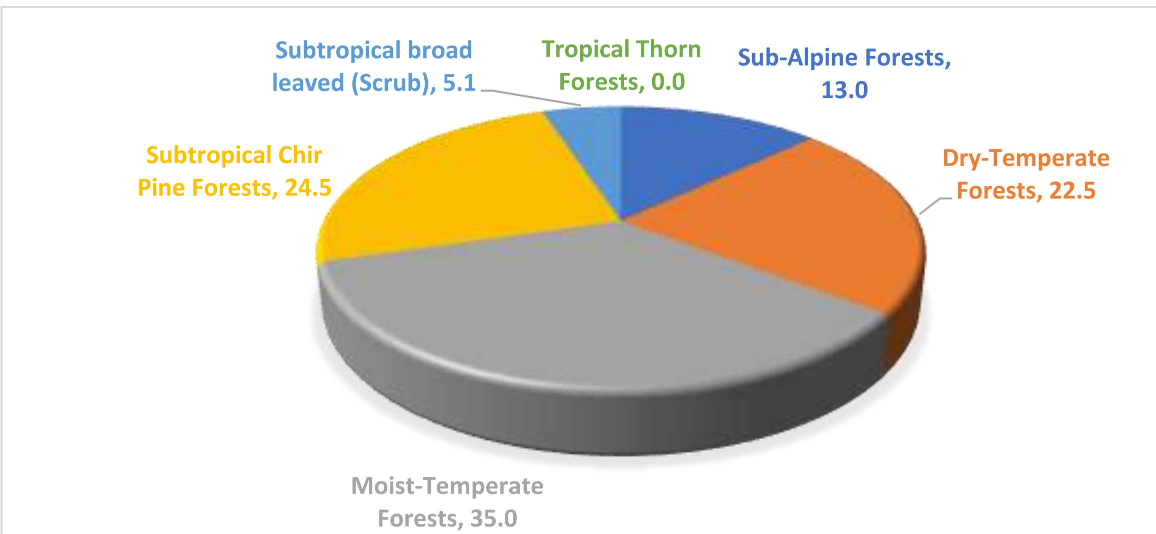

Figure 5: Forest type wise distribution of Emissions from Deforestation

Table 18: Forest type wise emissions from deforestation

Forest type	Forest-Cropland			Forest-Grassland			Forest-wetland			Forest-Settlement			Forest-Other land			Total Defor. (ha)	Total Emiss. (Mt CO2e)
	Defor. (ha)	EF (CO2e t/ha)	Emiss. (Mt CO2e)	Defor. (ha)	EF (CO2e t/ha)	Emiss. (Mt CO2e)	Defor. (ha)	EF (CO2e t/ha)	Emiss. (Mt CO2e)	Defor. (ha)	EF (CO2e t/ha)	Emiss. (Mt CO2e)	Defor. (ha)	EF (CO2e t/ha)	Emiss. (Mt CO2e)		
Sub-Alpine Forests	0.00	136.50	0.00	51.39	132.83	0.01	0.00	144.20	0.00	0.00	144.20	0.00	27.45	144.20	0.00	78.84	0.01
Dry-Temperate Forests	0.00	183.96	0.00	80.73	180.29	0.01	0.00	191.66	0.00	0.00	191.66	0.00	21.60	191.66	0.00	102.33	0.02
Moist-Temperate Forests	22.41	245.61	0.01	99.81	229.84	0.02	1.62	253.31	0.00	0.54	253.31	0.00	0.54	253.31	0.00	124.92	0.03
Subtropical Chir Pine Forests	81.90	143.27	0.01	65.88	127.87	0.01	0.00	150.97	0.00	1.71	150.97	0.00	0.00	150.97	0.00	149.49	0.02
Subtropical broad leaved (Scrub)	83.43	30.28	0.00	65.52	21.85	0.00	1.62	36.88	0.00	3.78	36.88	0.00	1.71	36.88	0.00	156.06	0.00
Tropical Thorn Forests	0.00	20.72	0.00	0.00	12.29	0.00	0.00	27.32	0.00	0.00	27.32	0.00	0.00	27.32	0.00	0.00	0.00
Total	**187.74**		**0.02**	**363.33**		**0.05**	**3.24**		**0.00**	**6.03**		**0.00**	**51.30**		**0.01**	**611.64**	**0.08**

4.7. Emission Factors for Forest Degradation

Emission factors for forest degradation were developed on the basis of changes in the canopy cover class within a forest type. Emission factors for forest degradation are given in Table 19. Uncertainties of EFs of degradation are given in Annex-14.

Table 19: Emissions factors for Forest Degradation

Forest Type	Dense - Medium		Dense - Sparse		Dense - Open		Medium - Sparse		Medium - Open		Sparse - Open	
	Δ C (t/ha)	ΔCO2e (t/ha)	ΔC (t/ha)	Δ CO2e (t/ha)	Δ C (t/ha)	ΔCO2e (t/ha)	Δ C (t/ha)	ΔCO2e (t/ha)	ΔC (t/ha)	ΔCO2e (t/ha)	ΔC (t/ha)	ΔCO2e (t/ha)
Sub-Alpine	19.80	72.60	51.22	187.82	58.12	213.09	31.42	115.22	38.32	140.49	6.89	25.27
Dry Temperate	29.39	107.77	57.31	210.15	87.58	321.13	27.92	102.38	58.19	213.36	30.27	110.98
Moist Temperate	51.34	188.26	73.68	270.16	92.43	338.91	22.34	81.91	41.09	150.66	18.75	68.75
Sub-tropical Pine	12.91	47.33	32.53	119.29	45.42	166.53	19.62	71.96	32.51	119.20	12.88	47.24
Subtropical broad leaved	4.46	16.37	21.18	77.65	27.52	100.91	16.71	61.28	23.06	84.54	6.34	23.26
Tropical Thorn	-	-	-	-	-	-	14.88	54.55	25.35	92.96	10.48	38.41

4.8. Emissions from Forest Degradation

Total emissions from forest degradation were estimated as 3.37 million tons CO_2e during 2016-2020 and the total enhancement from improvement in canopy cover was estimated as 5.80million tons CO_2e during this period. Thus, the net balance is removal of 2.43 million tons of CO_2e. The detail of forest type wise degradation and enhancement is given in Table 20.

Table 20: Emissions from Forest Degradation

Forest Type	Total degradation (ha)	Emissions (Mt CO2e)	Total enhancement (ha)	Removals (Mt CO2e)	Net Emissions/ Removals (Mt CO2e)
Sub-Alpine	640	0.044	531	0.032	0.013
Dry Temperate	2096	0.237	2595	0.285	-0.048
Moist Temperate	16602	2.327	27107	3.703	-1.377
Sub-tropical Pine	9558	0.551	23697	1.293	-0.742
Subtropical broad leaved (Scrub)	6283	0.208	19636	0.483	-0.275
Tropical Thorn*	23	0.001	120	0.001	0.000
Total	**35202**	**3.367**	**73686**	**5.796**	**-2.429**

* No Emission Factor (EF) available for canopy cover > 70 %

4.9. Removals from Enhancement

Under the present study removals were estimated both for the normal age of forests and the reporting period of four years (2016-2020). The total removal from enhancement due to reforestation and afforestation was estimated as 0.12 million tons of CO_2e for the normal age of forests. The largest share of CO_2 removal originated from moist temperate (34%), followed by sub-alpine forest (25%) and dry temperate (23%) as shown in(Table 21).

For the four-year period (2016 to 2020) the total removals from enhancement were assessed as 0.009 million tons of CO2e, with 30% removals originating from Moist Temperate Forests, 26% from Sub-Alpine Forests, 17% from Sub-Tropical Chir Pine Forest and 15% from Dry Temperate Forest (Table 21).

4.10. Overall picture of emissions and removals

Overall, a total of 2.355 million tons of CO_2e have been sequestered from reforestation, afforestation and improvement of forest cover density during 2016 to 2020 in AJK. The overall picture of emissions and removals from deforestation, forest degradation and enhancement in AJK is given in the

Table 22 below.

Table 21: Removals from enhancement

Forest type	Cropland-Forest			Grassland-Forest			Wetland-Forest			Settlement-Forest			Otherland-Forest			Total Enh. (ha)	Total Rem. during normal age of forest (Mt CO2e)	Total Rem. during 4 years (Mt CO2e)	%
	Enh. (ha)	RF (CO2e t/ha)	Rem. (Mt CO2e)	Enh. (ha)	RF (CO2e t/ha)	Enh. (ha)	RF (CO2e t/ha)	RF (CO2e t/ha)	Rem. (Mt CO2e)	Enh. (ha)	RF (CO2e t/ha)	Rem. (Mt CO2e)	Enh. (ha)	RF (CO2e t/ha)	Rem. (Mt CO2e)				
Sub-Alpine	0.00	136.50	0.00	38.70	132.83	0.01	0.00	144.20	0.00	0.00	144.20	0.00	174.60	144.20	0.03	213.30	0.03	0.0023	26.19
Dry-Temperate	0.00	183.96	0.00	58.86	180.29	0.01	0.00	191.66	0.00	0.00	191.66	0.00	89.82	191.66	0.02	148.68	0.03	0.0013	14.70
Moist-Temperate	26.46	245.61	0.01	129.06	229.84	0.03	0.54	253.31	0.00	0.00	253.31	0.00	20.16	253.31	0.01	176.22	0.04	0.0026	29.52
Subtropical Chir Pine	63.09	143.27	0.01	68.58	127.87	0.01	3.60	150.97	0.00	0.54	150.97	0.00	1.08	150.97	0.00	136.89	0.02	0.0015	17.40
Subtropical broad leaved (Scrub)	69.39	30.28	0.00	99.72	21.85	0.00	6.21	36.88	0.00	2.07	36.88	0.00	0.00	36.88	0.00	177.39	0.00	0.0011	12.12
Tropical Thorn	0.00	20.72	0.00	1.98	12.29	0.00	0.00	27.32	0.00	0.00	27.32	0.00	1.08	27.32	0.00	3.06	0.00	0.0000	0.07
Total	**158.94**		**0.02**	**396.90**		**0.06**	**10.35**		**0.00**	**2.61**		**0.00**	**286.74**		**0.05**	**855.54**	**0.12**	**0.0089**	**100.00**

Table 22: Overall carbon emissions and removals in AJK

Forest Type	Emissions from deforestation (Mt CO2e)	Emissions from forest degradation (Mt CO2e)	Removals from enhancement (Mt CO2e)	Removals from improvement in forest cover density (Mt CO2e)	Net balance (Mt CO2e)
Sub-Alpine	0.011	0.044	0.002	0.032	0.020
Dry Temperate	0.019	0.237	0.001	0.285	-0.031
Moist Temperate	0.029	2.327	0.003	3.703	-1.349
Sub-tropical Pine	0.020	0.551	0.002	1.293	-0.723
Subtropical broad leaved	0.004	0.208	0.001	0.483	-0.272
Tropical Thorn	0.000	0.001	0.000	0.001	0.000
Total	**0.083**	**3.368**	**0.009**	**5.797**	**-2.355**

5. RECOMMENDATIONS FOR IMPROVEMENT

5.1. Improvement of Activity Data

Instead of using post-monsoon, cloud-free, least haze a single image, in the era of data-cube, intense temporal coverage of Landsat 8 and 9, it is recommended to use an annual composite for the image classification. The yearly composite will better understand phonological stages to distinguish vegetation classes (Cropland, Shrubland, etc.) from the forest.

Instead of relying only on the spectral response of the images, it is recommended to integrate spectral indices of vegetation, water, snow, soil, etc. along with the spectral reflectance. In terms of forest degradation, the combination of SMA and time series could improve the results.

There is strong need for improvement of the forest ecological and forest types boundaries and maps. The forest ecological zones and forest types mapping prepared during the NFMS development phase, while used during the current assignment resulted in miss classification of forest types. Though the WWF-Pakistan GIS and Forestry experts tried to correct these mistakes and adjust the maps using local knowledge about the area and VHR Google maps, however further improvement is needed to avoid any miss classification.

Though, ground data from the forest inventory were used along with high resolution imageries and local knowledge (through meetings with local experts and their feedback) for validating LULC mapping and change detection, however separate and elaborate ground truthing needs to be conducted by the GIS/ RS team for generating more reliable LULC statistics and activity data regarding deforestation, enhancement and forest degradation.

5.2. Improvement of Emission Factors

The emission factors of deforestation and forest degradation are based on national average values of carbon stocks in different forest types. Thus, these are good for estimating emissions at national level. Emission factors at subnational level could not be developed due to the reason that the number of sample plots used for data collection were statistically not sound at subnational level and the resultant standard errors were quite large. The limited number of sample plots at Sub-National level were due to limited time for the assignment. However, it is recommended to develop emission factors at subnational level by taking statistically sufficient number of sample plots at the subnational level.

Forest degradation was included in the current GHG-Inventory report to develop emission factors for degradation using canopy cover as the proxy variable for estimating forest degradation. However, this method is not perfect as sometimes canopy cover does not exhibit the real picture of degradation or enhancement of carbon stocks in forest. The methodology needs further improvement and adoption of other proxy indicators. Permanent sample plots should be established for continuous monitoring of the forest carbon stocks and assessment of forest growth and biomass as well as forest degradation.

The current GHG-Inventory was confined to forest land use class while for the five non-forest land use classes IPCCs recommended default values of carbon densities were adopted. There is a dire need to develop emission factors for other land uses to get reliable estimates of emissions and removal for land use and landcover changes.

Locally developed allometric models can yield Tier 3 level estimates of carbon stocks and emissions. There is already a representative selection of allometric biomass models existing for the temperate forests, subtropical and riverine forests but it is recommended to develop biomass models for tree species found in other forest types and strata particularly for mangrove species.

Manual recording of field survey data on paper data-sheets need to be replaced by Mobile Data Entry Aps (FAO Opensource Aps) to save time and reduce errors in data entry and recording as well as increase transparency and ensure quality. This will need proper training of the forest inventory teams.

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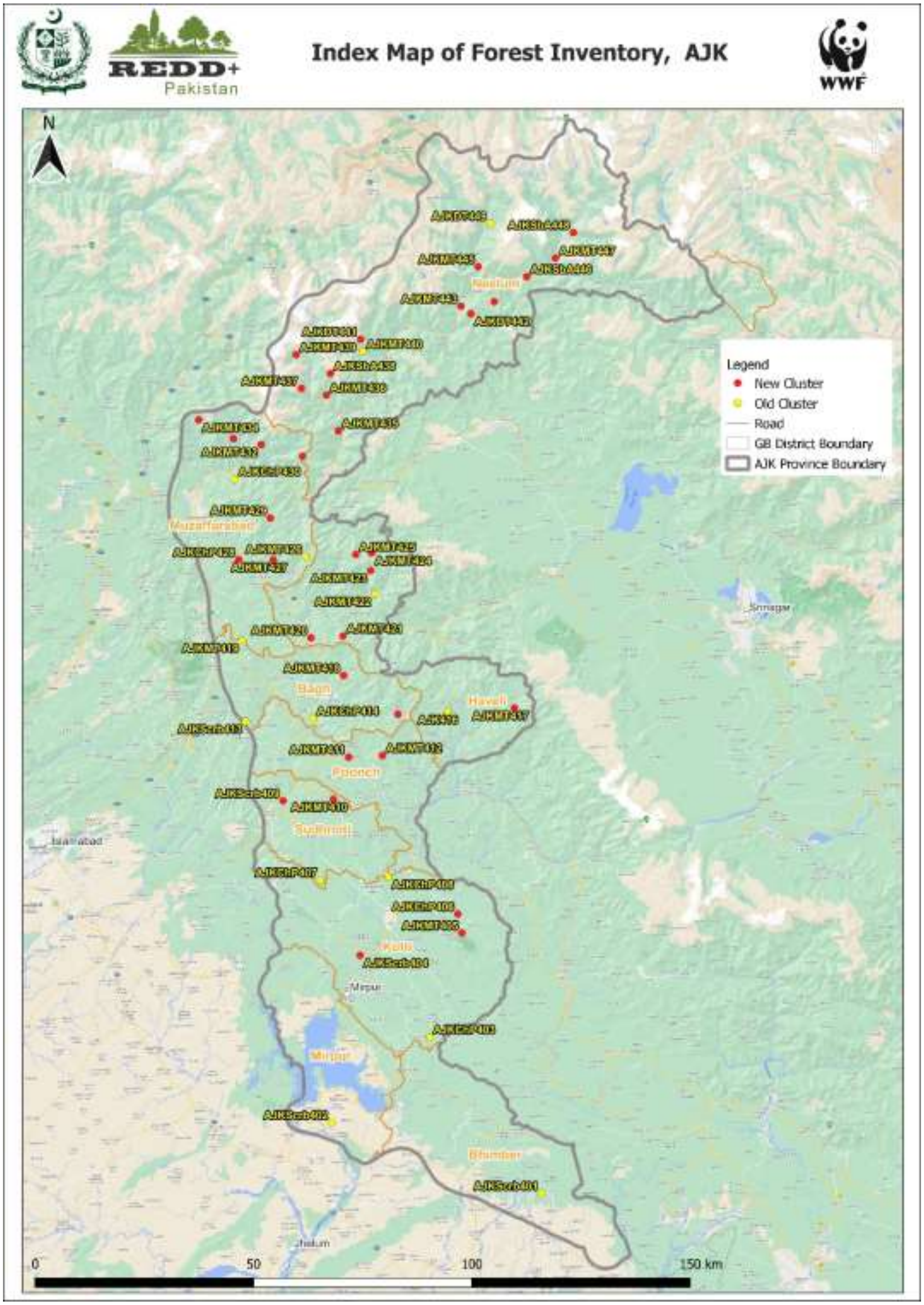
7. ANNEXES

Annex 1. Forest Inventory Plots Location Map (AJK)



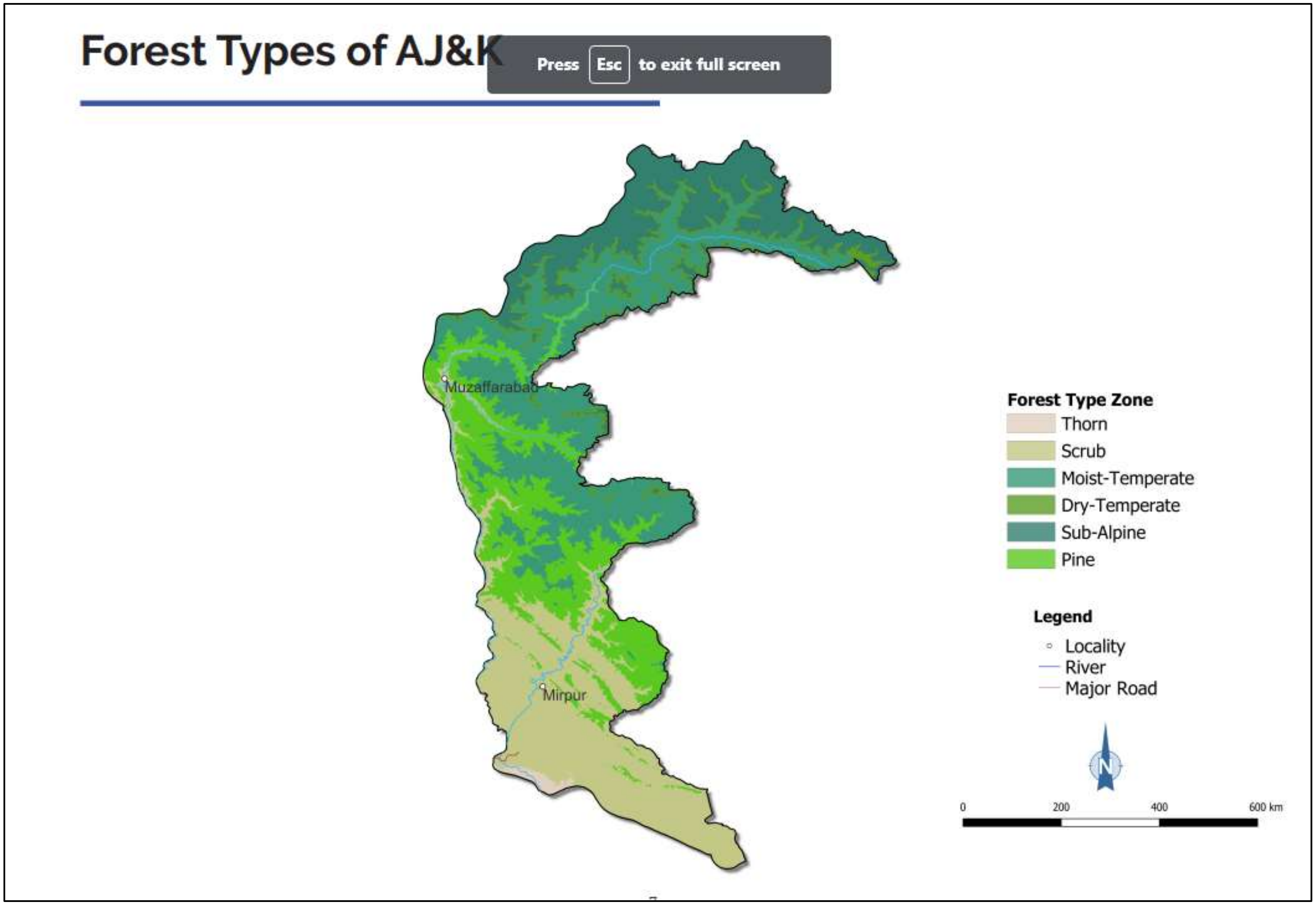
Annex-2: Coordinates of forest inventory sample plots (clusters) in AJK

Cluster No	Cluster ID	Cluster Plot	Latitude	Longitude	UTM-Projection	Elevation	Slope	Aspect
435	AJKMT435	AJKMT435-5	3820390	392486.5	EPSG: 32643	1918	45.43628	109.1232
436	AJKMT436	AJKMT436-5	3828691	390262.6	EPSG: 32643	2413	31.15561	246.6823
437	AJKMT437	AJKMT437-5	3830590	384669	EPSG: 32643	2777	27.57122	8.25944
438	AJKSbA438	AJKSbA438-5	3833612	391492	EPSG: 32643	3715	22.28646	252.8476
439	AJKMT439	AJKMT439-5	3838326	383911.9	EPSG: 32643	2790	40.82045	358.3477
440	AJKMT440	AJKMT440-5	3838172	399182.2	EPSG: 32643	2115	9.97274	130.7636
441	AJKDT441	AJKDT441-5	3840964	398828	EPSG: 32643	3129	32.9934	153.605
442	AJKDT442	AJKDT442-5	3845297	424320.2	EPSG: 32643	2637	26.09765	157.4569
443	AJKMT443	AJKMT443-5	3847166	422161.2	EPSG: 32643	2073	39.07727	320.7992
444	AJKMT444	AJKMT444-5	3847748	429805.7	EPSG: 32643	2875	20.8486	211.866
445	AJKMT445	AJKMT445-5	3855925	426619.3	EPSG: 32643	2079	25.64272	99.94057
446	AJKSbA446	AJKSbA446-5	3852963	437545.3	EPSG: 32643	2339	28.08047	4.46716
447	AJKMT447	AJKMT447-5	3856813	444347	EPSG: 32643	2226	46.30038	284.2296
448	AJKSbA448	AJKSbA448-5	3862393	448769.6	EPSG: 32643	2917	30.77579	37.72499
449	AJKDT449	AJKDT449-5	3865587	429930	EPSG: 32643	3077	40.6139	301.0717
414	AJKChP414	AJKChP414-5	3755156	382875	EPSG: 32643	1362	15.21359	353.8534
415	AJKMT415	AJKMT415-5	3754941	402267.7	EPSG: 32643	1978	46.25872	287.7648
418	AJKMT418	AJKMT418-5	3764543	390401.9	EPSG: 32643	2073	14.63082	14.93142
401	AJKScrb401	AJKScrb401-5	3643826	428710	EPSG: 32643	439	11.42219	253.3008
413	AJKScrb413	AJKScrb413-5	3755359	367469.4	EPSG: 32643	664	31.07251	309.4128
419	AJKMT419	AJKMT419-5	3773839	367728	EPSG: 32643	1823	33.12275	347.3914

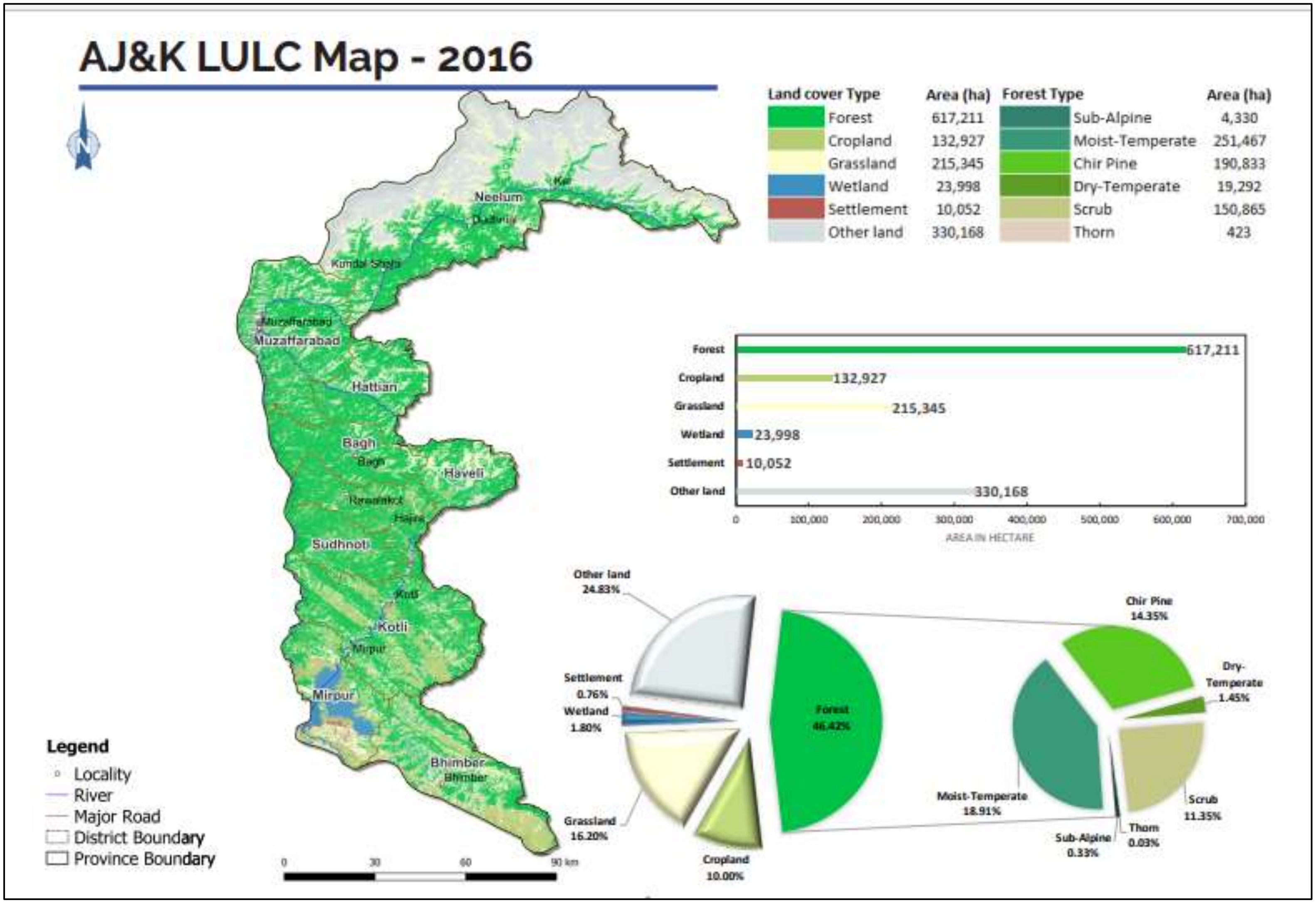
Cluster No	Cluster ID	Cluster Plot	Latitude	Longitude	UTM-Projection	Elevation	Slope	Aspect
405	AJKMT405	AJKMT405-5	3704255	413963.9	EPSG: 32643	1609	16.91662	37.87498
406	AJKChP406	AJKChP406-5	3708626	413266.8	EPSG: 32643	968	28.87603	168.1785
420	AJKMT420	AJKMT420-5	3773581	383467	EPSG: 32643	1864	36.46216	277.5947
421	AJKMT421	AJKMT421-5	3773545	390791.3	EPSG: 32643	2387	25.87083	123.9965
422	AJKMT422	AJKMT422-5	3782700	398578	EPSG: 32643	1650	36.7061	314.5061
423	AJKMT423	AJKMT423-5	3788093	397997.9	EPSG: 32643	2452	37.78506	229.3251
424	AJKMT424	AJKMT424-5	3792110	398446.8	EPSG: 32643	2589	32.01783	342.2996
425	AJKMT425	AJKMT425-5	3791983	394842	EPSG: 32643	2506	17.66609	302.9885
416	AJKMT416	AJKMT416-5	3754826	413685.2	EPSG: 32643	2299	23.04222	116.5651
417	AJKMT417	AJKMT417-5	3754833	428925.3	EPSG: 32643	2153	44.54972	198.2793
403	AJKChP403	AJKChP403-5	3680979	405253	EPSG: 32643	1117	11.20298	188.4712
408	AJKChP408	AJKChP408-5	3718018	397886	EPSG: 32643	1077	9.20292	264.8056
402	AJKScrb402	AJKScrb402-5	3662756	381746	EPSG: 32643	276	2.55705	150.9454
426	AJKMT426	AJKMT426-5	3792120	383320	EPSG: 32643	2102	36.46047	291.7323
427	AJKMT427	AJKMT427-5	3791891	375903.1	EPSG: 32643	2049	43.57399	94.12759
428	AJKChP428	AJKChP428-5	3792381	368019	EPSG: 32643	1311	40.16164	50.31454
429	AJKMT429	AJKMT429-5	3801436	375820.7	EPSG: 32643	2510	46.65781	254.8828
430	AJKChP430	AJKChP430-5	3810810	368250	EPSG: 32643	1708	28.82225	55.36632
431	AJKDT431	AJKDT431-5	3815123	383969	EPSG: 32643	3058	32.83403	126.2095
432	AJKMT432	AJKMT432-5	3818306	374727.4	EPSG: 32643	2589	35.83313	203.3768
433	AJKMT433	AJKMT433-5	3820037	368455.2	EPSG: 32643	2119	34.30804	195.7512
434	AJKMT434	AJKMT434-5	3824780	360799.7	EPSG: 32643	2904	42.93508	88.19126

Cluster No	Cluster ID	Cluster Plot	Latitude	Longitude	UTM-Projection	Elevation	Slope	Aspect
407	AJKChP407	AJKChP407-5	3718194	382420	EPSG: 32643	1052	20.38588	350.9605
409	AJKScrb409	AJKScrb409-5	3736773	374929.6	EPSG: 32643	745	15.46214	308.211
410	AJKMT410	AJKMT410-5	3736434	386406.6	EPSG: 32643	1815	18.88721	338.8602
411	AJKMT411	AJKMT411-5	3745823	390471.1	EPSG: 32643	1693	6.62881	180
412	AJKMT412	AJKMT412-5	3745738	398181.2	EPSG: 32643	1965	19.18057	18.43495
404	AJKScrb404	AJKScrb404-5	3700494	390445.8	EPSG: 32643	798	13.22231	49.76364

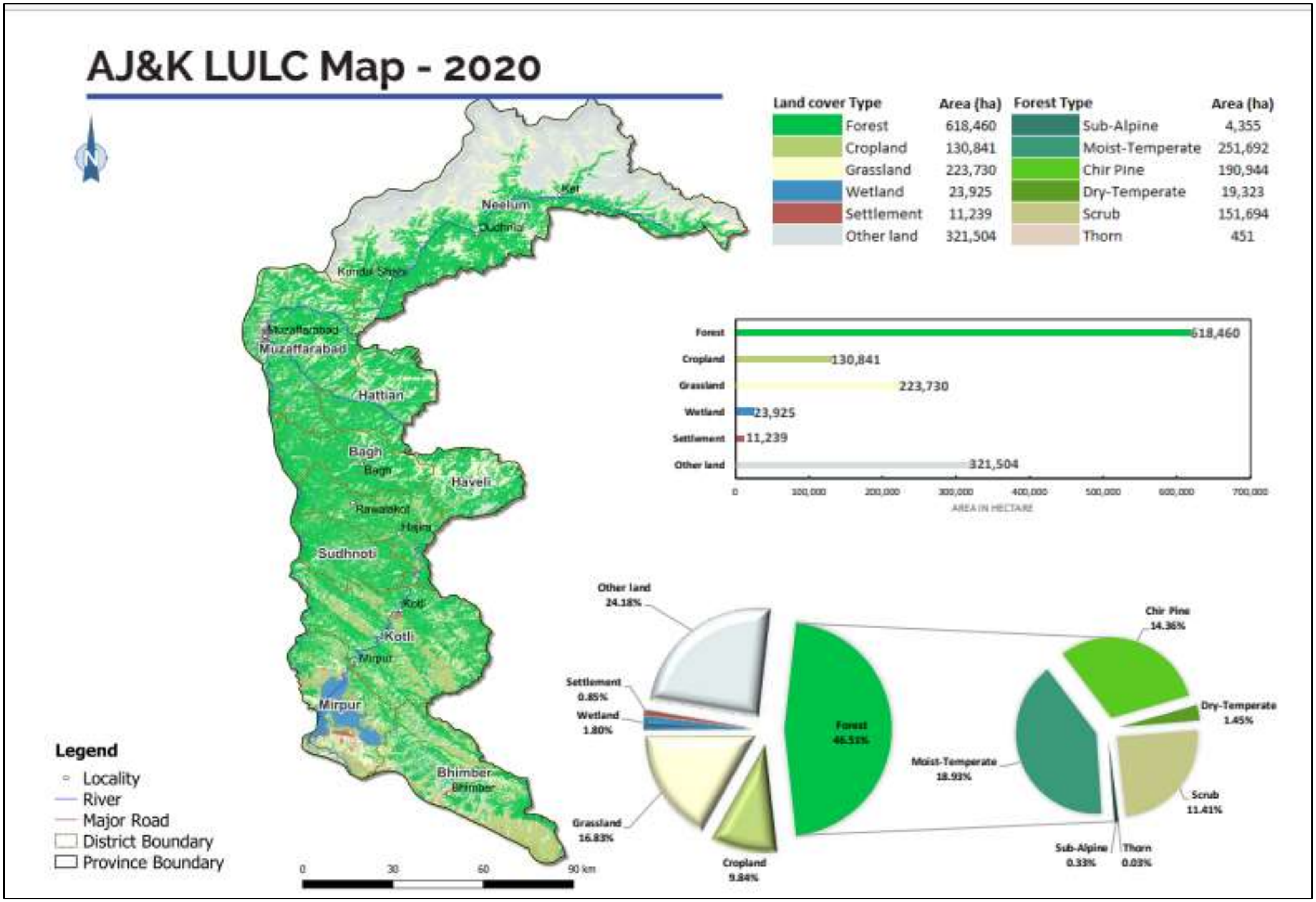
Annex-3: Forest types maps of AJK



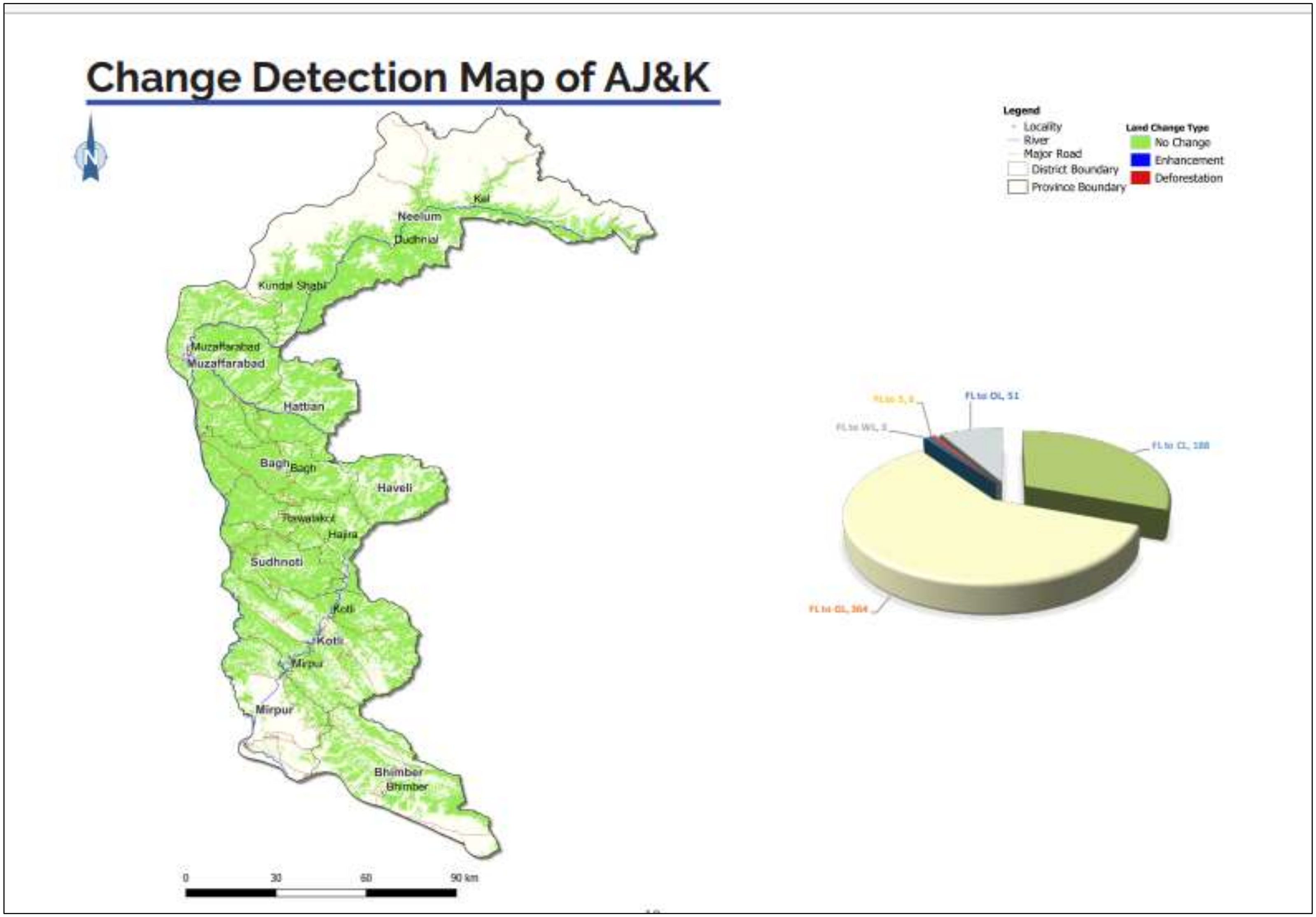
Annex-4: LULC Map of AJK for 2016



Annex-5: LULC Map of AJK (2020)



Annex 6. Land Use Land Cover Change Map of AJK



Annex-7. Wood Densities by Species (adopted from National FREL/ FRL Report 2020)

Species		Wood Density (ton/m3)	Species	Wood Density (ton/m3)
Abies pindrow		0.420	Juniperus excelsa	0.504
Acacia catechu		0.801	Leucaena leucocephala	0.450
Acacia modesta		0.835	Mallotus philippinensis	0.676
Acacia nilotica		0.689	Malus domestica	0.610
Aesculus indica		0.465	Melia azedarach	0.451
Ailanthus altissima		0.536	Millingtonia hortensis	0.640
Albizia lebbeck		0.596	Monotheca buxifolia	0.851
Albizia procera		0.587	Morus alba	0.578
Alnus nitida		0.370	Olea ferruginea	0.887
Armenian plum		0.675	Picea smithiana	0.430
Avicennia marina		0.650	Pinus gerardiana	0.500
Azadirachta indica		0.620	Pinus roxburghii	0.327
Betula utilis		0.500	Pinus wallichiana	0.430
Bombax cieba		0.350	Pongamia pinnata	0.640
Capparis decidua		0.691	Populus caspica	0.370
Cedrela serrata		0.390	Populus deltoides	0.417
Cedrus deodara		0.430	Prosopis cineraria	0.663
Celtis australis		0.550	Prosopis juliflora	0.800
Celtis eriocarpa		0.549	Prunus bokharensis	0.548
Ceriops tagal		0.758	Prunus spp.	0.606
Cordia myxa		0.330	Punica granatum	0.771
Dalbergia sissoo		0.760	Pyrus pashia	0.643
Diospyros lotus		0.706	Quercus incana	0.635
Dodonaea viscosa		0.840	Rhizophora mucronata	0.820
Ehretia acuminata		0.526	Robinia robesta	0.610
Ehretia spp.		0.526	Salix acmophylla	0.424
Eucalyptus camaldulensis		0.570	Salix tetrasperma	0.340
Eucalyptus citriodora		0.830	Salvadora oleoides	0.594
Ficus religiosa		0.443	Schinus molle	0.525
Ficus sp.		0.443	Syzygium cumini	0.760
Gmelina arborea		0.560	Tamarix aphylla	0.640
Grewia optiva		0.646	Tecomella undulata	0.500
Juglans regia		0.533	Ulmus wallichiana	0.440
			Zizyphus mauritiana	0.583

Annex-8: Revised Forest measurement manual (provided as separate file)

Annex-9: Data Storage and Processing report (provided as separate file)

Annex-10: Forest type and pool wise breakup of carbon densities (with and without SOC)

Forest Type	AGC (t/ha)	BGC (t/ha)	DWC (t/ha)	Litter (t/ha)	Total (t/ha)	SOC (t/ha)	Total with SOC (t/ ha)
Sub-Alpine	31.5	7.9	0.01	0	39.3	26.9	66.2
Dry Temperate	41.7	10.4	0.09	0.001	52.3	49.3	101.6
Moist Temperate	55.2	13.8	0.09	0.001	69.1	51.8	120.9
Sub-tropical Chir Pine	32.9	8.2	0.03	0.001	41.2	48.0	89.2
Subtropical broad leaved (Scrub)	8	2	0.02	0.002	10.1	25.0	35.1
Tropical Thorn/ dry deciduous broad leaved	5.9	1.5	0.01	0.009	7.5	27.8	35.3

Annex-11: Details of emissions from forest degradations

Forest Type	Dense - Medium			Dense - Sparse			Dense - Open			Medium - Sparse			Medium - Open			Sparse - Open			Total	
	EF/RF CO2e (t/ha)	Deg. (ha)	Emis (Mt CO2e)	EF/RF CO2e (t/ha)	Deg. (ha)	Emis (Mt CO2e)	EF/RF CO2e (t/ha)	Deg. (ha)	Emis (Mt CO2e)	EF/RF CO2e (t/ha)	Deg. (ha)	Emis (Mt CO2e)	EF/RF CO2e (t/ha)	Deg. (ha)	Emis (Mt CO2e)	EF/RF CO2e (t/ha)	Deg. (ha)	Emis (Mt CO2e)	Deg. (ha)	Emis (Mt CO2e)
Sub-Alpine	72.6	39	0.003	187.8	6	0.001	213.1	1	0.000	115.2	257	0.030	140.5	19	0.003	25.3	319	0.008	640	0.044
Dry-Temperate	107.8	619	0.067	210.2	64	0.013	321.1	5	0.002	102.4	873	0.089	213.4	60	0.013	111.0	475	0.053	2,096	0.237
Moist-Temperate	188.3	8,022	1.510	270.2	579	0.157	338.9	65	0.022	81.9	4,703	0.385	150.7	373	0.056	68.7	2,859	0.197	16,602	2.327
Subtropical Chir Pine	47.3	5,735	0.271	119.3	275	0.033	166.5	26	0.004	72.0	2,761	0.199	119.2	108	0.013	47.2	655	0.031	9,558	0.551
Subtropical broad leaved (Scrub)	16.4	3,772	0.062	77.7	166	0.013	100.9	20	0.002	61.3	1,870	0.115	84.5	102	0.009	23.3	353	0.008	6,283	0.208
Tropical Thorn	-	11	-	-	2	-	-	1	-	54.5	5	0.000	93.0	1	0.000	38.4	3	0.000	23	0.001
Total		**18,199**	**1.913**		**1,092**	**0.217**		**117**	**0.030**		**10,468**	**0.818**		**663**	**0.093**		**4,664**	**0.297**	**35,202**	**3.367**

Annex-12: Details of removals from improvement in forest cover density

Forest Type	Medium-Dense			Sparse-Dense			Open-Dense			Sparse-Medium			Open-Medium			Open-Sparse			Total	
	EF/RF CO2e (t/ha)	Enh. (ha)	Rem (Mt CO2e)	EF/RF CO2e (t/ha)	Enh. (ha)	Rem (Mt CO2e)	EF/RF CO2e (t/ha)	Enh. (ha)	Rem (Mt CO2e)	EF/RF CO2e (t/ha)	Enh. (ha)	Rem (Mt CO2e)	EF/RF CO2e (t/ha)	Enh. (ha)	Rem (Mt CO2e)	EF/RF CO2e (t/ha)	Enh. (ha)	Rem (Mt CO2e)	Enh. (ha)	Rem CO2e (t/ha)
Sub-Alpine	72.6	57	0.004	187.8	4	0.001	213.1	0	0.000	115.2	159	0.018	140.5	6	0.001	25.3	305	0.008	531	0.032
Dry-Temperate	107.8	742	0.080	210.2	33	0.007	321.1	4	0.001	102.4	833	0.085	213.4	22	0.005	111.0	961	0.107	2,595	0.285
Moist-Temperate	188.3	13,516	2.544	270.2	447	0.121	338.9	31	0.010	81.9	8,193	0.671	150.7	226	0.034	68.7	4,694	0.323	27,107	3.703
Subtropical Chir Pine	47.3	17,001	0.805	119.3	421	0.050	166.5	17	0.003	72.0	5,289	0.381	119.2	123	0.015	47.2	847	0.040	23,697	1.293
Subtropical broad leaved (Scrub)	16.4	16,024	0.262	77.7	361	0.028	100.9	19	0.002	61.3	2,851	0.175	84.5	113	0.010	23.3	269	0.006	19,636	0.483
Tropical Thorn	-	101	-	-	5	-	-	1	-	54.5	9	0.0	93.0	3	0.0	38.4	2	0.0	120	0.001
Total		**47,441**	**3.696**		**1,270**	**0.207**		**71**	**0.016**		**17,334**	**1.330**		**492**	**0.064**		**7,077**	**0.483**	**73,686**	**5.796**

Annex-13: Uncertainties of Emission Factors of deforestation

Forest Type	Forest Carbon Density t/ha	SE%	EF (t/ha)	SE EF (t/ha)	Sampling Error (t/ha)	95% CI	
EF deforestation overall (Forest to wetlands/ settlement/ other land)							
Sub-Alpine Forests	39.33	20.56	242.79	49.92	97.84	144.95	340.63
Dry-Temperate Forests	52.27	11.82	372.43	44.01	86.27	286.16	458.70
Moist-Temperate Forests	69.08	12.21	443.37	54.13	106.10	337.27	549.46
Subtropical Chir Pine Forests	41.17	16.22	326.89	53.03	103.94	222.95	430.83
Subtropical broad leaved (Scrub)	10.06	15.26	209.03	31.90	62.53	146.50	271.57
Tropical Thorn/ dry deciduous broad-leaved Forests	7.45	25.74	129.21	33.26	65.19	64.01	194.40
EF deforestation (Forest to cropland)							
Sub-Alpine Forests	39.33	20.56	136.50	28.07	55.01	81.49	191.51
Dry-Temperate Forests	52.27	11.82	183.96	21.74	42.61	141.35	226.57
Moist-Temperate Forests	69.08	12.21	245.61	29.99	58.77	186.84	304.38
Subtropical Chir Pine Forests	41.17	16.22	143.27	23.24	45.56	97.71	188.82
Subtropical broad leaved (Scrub)	10.06	15.26	30.28	4.62	9.06	21.22	39.34
Tropical Thorn/ dry deciduous broad-leaved Forests	7.45	25.74	20.72	5.33	10.46	10.27	31.18
EF deforestation (Forest to grassland)							

Sub-Alpine Forests	39.33	20.56	132.83	27.31	53.53	79.30	186.36
Dry-Temperate Forests	52.27	11.82	180.29	21.31	41.76	138.53	222.05
Moist-Temperate Forests	69.08	12.21	229.84	28.06	55.00	174.84	284.84
Subtropical Chir Pine Forests	41.17	16.22	127.87	20.74	40.66	87.21	168.53
Subtropical broad leaved (Scrub)	10.06	15.26	21.85	3.33	6.54	15.31	28.39
Tropical Thorn/ dry deciduous broad-leaved Forests	7.45	25.74	12.29	3.16	6.20	6.09	18.49

Annex-14: Uncertainties of Emission Factors of Forest Degradation

Annex-14: (Part-a)

Forest Type	Dense - Medium							Dense - Sparse						
	ΔC (t/ha)	ΔCO2e (t/ha)	SE%	SE ΔCO2e (t/ha	Samp. Error (t/ha)	95% CI		ΔC (t/ha)	ΔCO2e (t/ha)	SE%	SE ΔCO2e (t/ha	Samp. Error (t/ha)	95% CI	
Sub-Alpine	19.80	72.60	8.80	6.39	12.52	-3.72	21.32	51.22	187.82	10.65	20.00	39.21	-28.56	49.86
Dry Temperate	29.39	107.77	17.28	18.62	36.49	-19.22	53.77	57.31	210.15	25.87	54.37	106.57	-80.70	132.44
Moist Temperate	51.34	188.26	19.79	37.25	73.02	-53.23	92.81	73.68	270.16	22.18	59.93	117.47	-95.29	139.65
Sub-tropical Chir Pine	12.91	47.33	22.38	10.59	20.76	1.62	43.14	32.53	119.29	24.36	29.06	56.95	-32.59	81.31
Subtropical broad leaved (Scrub)	4.46	16.37	36.44	5.96	11.69	24.75	48.12	21.18	77.65	37.75	29.31	57.45	-19.70	95.19
Tropical Thorn/ dry deciduous	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Annex-14: (Part-b)

Forest Type	Dense-Open							Medium-Sparse						
	ΔC (t/ha)	ΔCO2e (t/ha)	SE%	SE ΔCO2e (t/ha)	Samp. Error (t/ha)	95% CI		ΔC (t/ha)	ΔCO2e (t/ha)	SE%	SE ΔCO2e (t/ha)	Samp. Error (t/ha)	95% CI	
Sub-Alpine	58.12	213.09	5.21	213.09	5.21	0.00	10.41	31.42	115.22	13.82	15.92	31.20	-17.38	45.01
Dry Temperate	87.58	321.13	63.77	321.13	63.77	0.00	127.55	27.92	102.38	21.35	21.86	42.85	-21.50	64.20
Moist Temperate	92.43	338.91	33.46	338.91	33.46	0.00	66.92	22.34	81.91	14.96	12.25	24.02	-9.06	38.97
Sub-tropical Chir Pine	45.42	166.53	28.12	166.53	28.12	0.00	56.24	19.62	71.96	26.81	19.29	37.81	-11.00	64.61
Subtropical broad leaved (Scrub)	27.52	100.91	34.60	100.91	34.60	0.00	69.21	16.71	61.28	21.77	13.34	26.15	-4.38	47.92
Tropical Thorn/ dry deciduous	-	-	-	-	-	-	-	14.88	54.55	89.40	48.77	95.58	-6.18	184.98

Annex-14: (Part-c)

Forest Type	Medium-Open							Open-Sparse						
	ΔC (t/ha)	ΔCO2e (t/ha)	SE%	SE ΔCO2e (t/ha)	Samp. Error (t/ha)	95% CI		ΔC (t/ha)	ΔCO2e (t/ha)	SE%	SE ΔCO2e (t/ha)	Samp. Error (t/ha)	95% CI	
Sub-Alpine	38.32	140.49	10.22	14.36	28.15	-17.93	38.38	6.89	25.27	11.85	3.00	5.87	5.98	17.73
Dry Temperate	58.19	213.36	62.08	132.45	259.60	-197.52	321.68	30.27	110.98	65.00	72.13	141.38	-76.38	206.37
Moist Temperate	41.09	150.66	29.18	43.96	86.16	-56.98	115.33	18.75	68.75	30.85	21.21	41.57	-10.72	72.42
Sub-tropical Chir Pine	32.51	119.20	30.26	36.07	70.70	-40.44	100.97	12.88	47.24	31.75	15.00	29.40	2.35	61.16
Subtropical broad leaved (Scrub)	23.06	84.54	15.70	13.28	26.02	-10.32	41.72	6.34	23.26	18.54	4.31	8.45	10.09	26.99
Tropical Thorn/ dry deciduous	25.35	92.96	118.79	110.43	216.45	-97.66	335.25	10.48	38.41	80.66	30.98	60.73	19.93	141.38

Annex-15: Province wise uncertainties of Activity Data (Forest Loss)

Province	Forest loss area	Standard error	Variance (SE^2)	95 % CI	Uncertainty of AD Deforestation (2016-2020)
Azad Jammu and Kashmir	612	297	88209	582	95%
Balochistan	1046	619	383161	1,214	116%
Gilgit Baltistan	485	47	2209	92	19%
Khyber Pakhtunkhwa	7838	5926	35117476	11,615	148%
Punjab	7379	4607	21224449	9,030	122%
Sindh	27202	2386	5692996	4,677	17%
Islamabad Capital Territory	448	238	56644	467	104%
TOTAL	**45010**			**27,677**	

Annex-16: Mean Ages of Different Forest Types

Forest Type	Mean DBH (cm)	Mean Age (year)
Subalpine	34	52
Moist Temp	42	63
Dry Temperate	28	85
Dry Temperate Chilghoza	27	80
Subtropical Pine	28	48
Subtropical BL Scrub	17	17
Dry Tropical Thorn	17	34

Source: Ali, 2018; Ali, 2019 and Ali, 2020