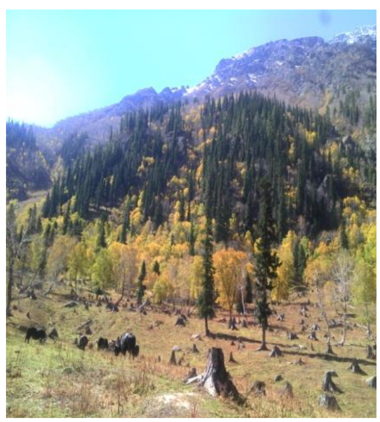
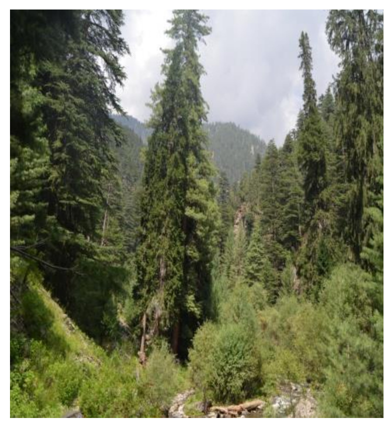
REPORT

ON

Forest Carbon Inventory of Gilgit Baltistan

By

Anwar Ali, Forest Mensuration Officer, PFI
Kiramat Hussain, GIS Specialist, GB REDD+ Program
Ismail, Focal Person, GB REDD+ Program
Kamran Hussain, NFI Expert, National REDD+ Office, MoCC

FORESTS, WILDLIFE AND ENVIRONMENT DEPARTMENT,
GILGIT BALTISTAN, GILGIT
2017

FOREWORD

Reducing Emissions from deforestation, forest degradation, conservation and enhancement of carbon stock and sustainable forest management titled as "REDD+" has emerged as a key international mechanism for climate change mitigation in forestry sector. Under this mechanism developed countries will provide incentives to developing countries to contribute to mitigation actions by voluntarily undertaking activities that reduce greenhouse gas (GHG) emissions and that enhance carbon sinks in the forest sector. UNFCCC calls upon the developing countries aiming to participate in the international REDD+ mechanism to undertake inventories of forest carbon stocks.

The Government of Gilgit Baltistan is actively participating in the national REDD+ Programme and has also initiated a REDD+ Project in 2010 with a total budget of Rs.30 million to achieve REDD+ readiness in Gilgit Baltistan. The project has achieved several milestones in the journey towards REDD+ implementation in Gilgit Baltistan which include formulation of Forest Policy and Laws, development of local volume tables, biomass tables, allometric models, establishment of GIS lab and capacity building of the officers and staff of Forest Department and local communities.

The current report on "Forest Carbon Inventory of Gilgit Baltistan" is the final outcome of two years hard work of data collection in the field. This document provides comprehensive information on carbon estimates in different forest types and strata of Gilgit Baltistan. It also provides district-wise data on land use, forest cover and carbon stock in GB. These information are vital for implementation of REDD+ programme in the region.

The REDD+ Focal Person for GB and his team deserve appreciation for their hard work, dedication and professional excellence in preparation of this document.

Sajjad Haider
Secretary to Government of Gilgit Baltistan
Forests, Wildlife & Environment Department

ACKNOWLEDGMENTS

This report has been prepared under the REDD+ Project of Gilgit Baltistan. I would like to take this opportunity to express my heartiest gratitude to all those organizations and individuals who provided support during the execution of this project.

Foremost I would like to thank Mr. Sajjad Haider, Secretary, Forest Wildlife and Environment Department, Gilgit Baltistan, for his kind support and keen interest in REDD+ initiative in Gilgit Baltistan. Thanks are also extended to Mr. Wilayat Noor, Conservator of Forests, Gilgit circle, Dr. Zakir Hussain, Conservator Forests, Baltistan Circle and Mr. Mehmood Ghaznavi Conservator of Forests, Diamer Circle.

The hard work undertaken by the data collection team particularly Mr. Kamran Hussain, Mr. Iftakhar Hussain DFO, Mr. Muhammad Essa, DFO, Mr. Zahid Hameed, RFO, Mr. Imran Hussain Changezi RFO, Raja Saleem Hussain RFO, Mr. Roman Ghayas, RFO, Mr. Sarmad Shafa, RFO, Mr. Shahzada Alam, RFO, Syed Naeem Abbas, RFO and Mr. Faizan Dukhi, RFO is highly appreciated and acknowledged.

The technical assistance provided by ICIMOD and Pakistan Forest Institute in designing the inventory and analysis of data is also gratefully acknowledged.

Last but not the least, I would like to thank all the officers and field staff of Gilgit Baltistan Forest Department and local communities who facilitated our data collection teams in the field.

Ismail
REDD+ Focal Person for
Gilgit- Baltistan

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List of Acronyms and Abbreviations

AGC	Aboveground Carbon
AGTB	Aboveground Tree Biomass
AGM	Aboveground Biomass
asl	Above Sea Level
BGC	Belowground Carbon
BL	Broad-Leaved
cm	Centimeter
C	Carbon
CO_2	Carbon dioxide
CV	Coefficient of Variation
DBH	Diameter at Breast height
DEM	Digital Elevation Model
FSMP	Forestry Sector Master Plan
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GB	Gilgit Baltistan
GHG	Green House Gases
GIS	Geographic Information System
GPS	Global Positioning System
ha	hectare
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Inter-governmental Panel on Climate Change
m	Meter
mm	millimeter

MRV	Measurement, Reporting and Verification
OBIA	Object Based Image Analysis
PFI	Pakistan Forest Institute
REDD+	Reducing Emissions from Deforestation, Forest Degradation, sustainable forest management, conservation and enhancement of forest carbon
RS	Remote Sensing
RSE	Relative Standard Error
SD	Standard Deviation
SE	Standard Error
SUPARCO	Space and Upper Atmosphere Research Commission
t	Tonne
UNFCCC	United Nations Framework Convention on Climate Change

SUMMARY

A terrestrial carbon inventory was conducted by the GB REDD+ Program during 2015-2016 to estimate carbon stock in the forests of Gilgit Baltistan. Forest area of the region was determined and mapped through object based image analysis (OBIA) of Sentinel-2 satellite imageries of 2016. The forest cover was classified into six forest strata on the basis of crown density and species composition to obtain more homogenous units for field inventory. These strata include dense conifers, dense mixed, dense broad-leaved, sparse conifers, sparse mixed and sparse broad-leaved forests. The total forest area of Gilgit Baltistan was estimated at 249,205 ha which make up 3.57% of the total area of the region. Diamer has the highest forest cover (71%) followed by Astore (12%) and Gilgit (10%). These three districts together contain 93% of the total forest area of Gilgit Baltistan.

Carbon stocks in different forest areas and strata were determined through a terrestrial carbon inventory. For this purpose data was collected from 537 sample plots each having area of 0.1 ha, laid out in different forest areas through a stratified random sampling design.

It was found that about 51 % (126,927 ha) of the forests are dense forests which have canopy cover of more than 35%. On the other hand about 49% (122,277 ha) are sparse forests which have crown density of less than 35%. The highest amount of forest cover falls under the dense coniferous class (43%) followed by sparse conifers (34%) and sparse broad-leaved forest (11%). The remaining forest cover consists of dense mix, dense broad-leaved and sparse mixed forests each having 4% cover.

The tree species sampled predominantly consisted of conifers (78%) with few broadleaved species (22%). Deodar (*Cedrus deodara*) is the dominant specie (23%) followed by Kail (*Pinus wallichiana*) with 22% and Spruce (Picea smithiana) with 20% share in the total growing stock. Fir (*Abies pindrow*) has 7% share in the total trees. Thus, 72% of the total growing stock consists of these four species. Juniper and Chilghoza have small proportions in total number of trees with 2.34% and 2.84% shares, respectively. Oak (*Quercus spp.*) is the dominant broad-leaved species recorded during the inventory with 15.31% followed by *Betula utilis* (Birch) with 6.98% contribution in the total trees. *Taxus wallichiana* (Yew) has only 0.21% share in the total trees sampled during the inventory.

The average stocking/density was estimated at 244 trees per ha. In dense and sparse forests, the average number of trees per ha were estimated at 356 and 111 respectively. Highest number of trees per unit area was found in Dense Pure Broad-Leaved Forest i.e. 660 trees/ha, followed by Dense Mixed forests with 405 trees/ha. Similarly dense coniferous forests have density of 332 trees/ha. On the other hand, Sparse Broad-leaved forests have 190 trees/ha, followed by sparse mixed forests 140 trees/ha and sparse conifers have 89 trees/ha.

The results of the inventory indicate that the forests of Gilgit Baltistan are mostly young. About 65% of the trees fall in immature class followed by sub-mature with 27.5% sample trees. Thus about 93% of the trees are young and only 7 % of the sample trees are mature. Higher numbers of trees in the younger classes have very high potential for carbon sequestration as growth rate is generally fast in these stages and they can sequester a large amount of carbon dioxide from the atmosphere. Thus, the forests of Gilgit Baltistan have high potential for REDD+.

The total carbon stock in aboveground and belowground biomass in the forests of Gilgit-Baltistan was estimated at 16.95 million ton. It was found that 80% of the carbon stock is in aboveground and 20% is in belowground pool. The highest amount of carbon stock is present in Dense Conifers (70%) followed by Sparse Conifers (14%). Dense Mixed forests have 5% share in the total carbon stock. Dense Broad-leaved and Sparse Broad-leaved forests have almost equal share in the total carbon stock i.e. 4.37% and 4.55% respectively. Similarly, sparse mixed forests have 2.09% share in the total carbon stock in the area.

The above ground carbon stock in the forests of Gilgit Baltistan was estimated at 13,590,410 ton. Weighted mean carbon stock was calculated at 54.53 ± 3.80 t/ha and weighted average sample error was determined as 6.97% (95% confidence interval).

It was found that 84% of the total aboveground carbon is present in dense forests whereas only 16% carbon is present in sparse forests. In dense forest, the above ground carbon stock was calculated at 87.43 t/ha ranging from 1.129 t/ha to 333.493 t/ha. On the other hand, in sparse forests, the aboveground carbon stock was 20.75 t/ha ranging from 0.069 t/ha to 155.165 t/ha. The highest carbon stock was found in dense coniferous forests as 91.65 t/ha, followed by dense broad-leaved as 60.78 t/ha and dense mixed as 25.77 t/ha. Similarly, in sparse conifers, sparse broad-leaved and sparse mixed forests, the aboveground carbon stocks were 20.00 t/ha, 18.74 and 25.77 t/ha respectively. It was estimated that the forests of Gilgit-Baltistan can sequester 1,283,406 tonne CO_2 per year.

1. INTRODUCTION

Climate Change is the most serious and complex environmental problem of the modern era arising due to increasing concentrations of atmospheric carbon dioxide (CO_2) and other Greenhouse Gases. Forests act as carbon storehouses and play an important role in influencing our climate. When forests are cleared, they release carbon and act as a source of carbon emissions. When they are restored, they sequester carbon and become a sink of carbon. The use of forests can therefore add to the problem of climate change, but it can also be a tool for climate change mitigation.

Realizing the importance of forests in climate change mitigation, negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) have been considering different options to include forestry in the global climate change agenda. Reducing emissions from deforestation, forest degradation, sustainable forest management, conservation and enhancement of forest carbon stocks known as REDD+ has emerged as a promising option for forest-based climate change mitigation in developing countries. Under the REDD+ programme, developed countries will provide incentives to the developing countries to keep their forests standing and thus help in reducing GHG emissions. UNFCCC calls upon the developing countries aiming to participate in the international REDD+ mechanism to develop a REDD+ Strategy, a Safeguards Information System, a Forest Monitoring System and Forest Reference Emission Level/ Forest Reference Level.

Pakistan being a signatory of the UNFCCC and the latest Paris Agreement has been contributing in the global efforts to mitigate climate change. In order to benefit from the international REDD+ mechanism, the government of Pakistan started REDD+ programme at national level. Similarly, provincial governments particularly Khyber Pakhtunkhwa and Gilgit Baltistan also initiated subnational projects to achieve REDD+ readiness in their respective provinces.

Gilgit-Baltistan is situated in the extreme north of Pakistan, bordering China and Afghanistan in the north (35˚-37’) and India in the east (72˚-75’), covering an area of 69685.6 square kilometers. The whole area falls within the high mountain ranges of Karakorum, Himalayas, Hindukush and Pamir with most of the area situated above 3,000 meters above sea level (Govt. of Pakistan, 2003).

Climatic conditions vary widely in the Gilgit-Baltistan, ranging from the monsoon-influenced moist temperate zone in the western Himalaya, to the arid and semi-arid cold desert in the northern Karakoram and Hindu Kush. Below 3,000 m, precipitation is minimal, rarely exceeding 200 mm annually. However, there is a strong gradient with altitude, and at 6,000 m, the equivalent of 2,000 mm per year falls as snow. Temperatures in the valley bottoms can vary from extremes of 40°C in summer to less than –10°C in winter (Govt. of Pakistan, 2003). The total forest area of Gilgit Baltistan is 249205 ha. Ecologically most of the forest areas can be classified as dry temperate where *Cedrus deodara* (Deodar) is the dominant species with *Pinus wallichiana* (Kail), *Abies pindrow* (Fir), *Picea smithiana* (Spruce), *Pinus gerardiana* (Chilghoza) and *Quercus ilex* (Oak) as the key associates (Akbar et al., 2011).

Most of the area of Gilgit Baltistan consists of rugged mountains, the higher elevations remaining snow covered throughout the year. This area hosts several highest peaks in the world including K2 and Nanga Parbat. Due to the presence of invaluable glaciers, these mountains are important source of water for downstream plains of Pakistan. The mountains provide opportunity for climbing, trekking and hiking besides being home to forests and important habitats of high altitude plants and animals. The natural forests of Gilgit Baltistan are an important source of softwood timber for the country. Locally, they provide timber; firewood; torch wood; grazing; medicinal plants and other non-timber forest products (NTFP) .They have great potential for countryside recreation and eco-tourism.

The emergence of REDD+ as a promising option for climate change mitigation, has added a new dimension to the importance of forests. Under this mechanism, developing countries will be rewarded for keeping their forests standing for carbon sequestration. In order to benefit from REDD+, the Government of Gilgit Baltistan initiated a project for REDD+ Preparation in Gilgit Baltistan in 2013.

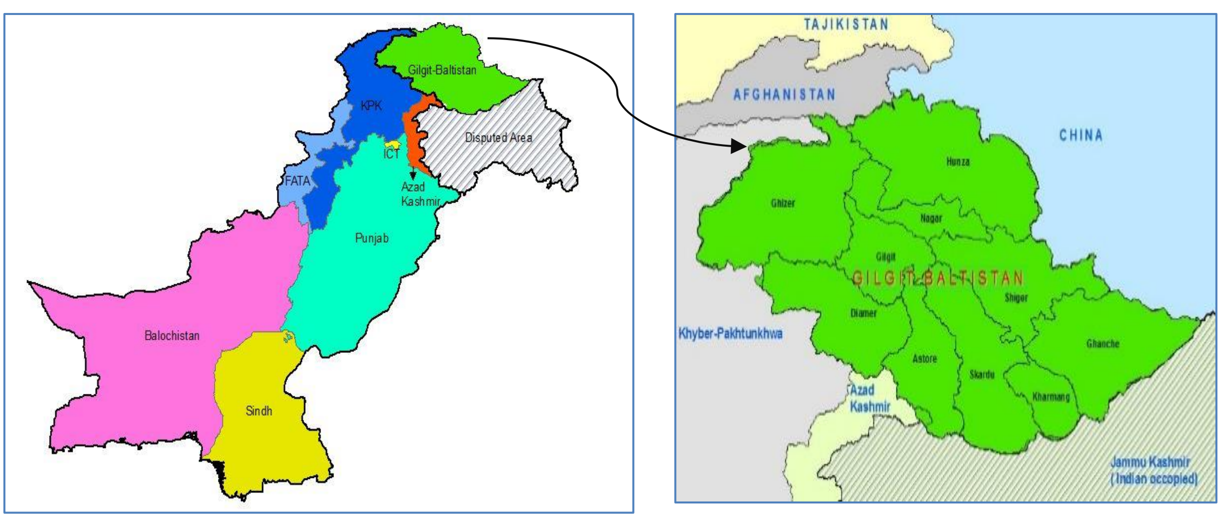
The Gilgit Baltistan REDD+ Project undertook this study to measure carbon stock in the aboveground biomass of the forest ecosystem through a combination of terrestrial forest inventory and satellite data based forest cover mapping. The main objective of this study was to quantify carbon stock in the aboveground biomass of the forest of Gilgit Baltistan. Determination of forest area, its stratification, mapping and determination of carbon sequestration potential were also some of the objectives of the study. This study covers the measurement component of Monitoring, Reporting and Verification (MRV) system. The study also yields local emission factors for forestry sector of Gilgit Baltistan which can be used to estimate GHG inventory for the area.

2. Methodology

Forest carbon inventory was conducted through the GB REDD+ Programme during 2015-16. The inventory estimated forest area under different forest types and strata and the carbon density in each strata to assess current carbon stock in the forest. Forest area was determined through remote sensing and GIS and the carbon density was determined through field measurement. In order to achieve tier 3 level carbon estimates for aboveground carbon in the forests of Gilgit- Baltistan, local allometric equations, biomass expansion factors and basic wood densities were determined through destructive sampling. The detail of methods employed for these operation are given in the following sections.

2.1 Forest Cover Classification and Mapping

Forest carbon stock assessment requires data on forest cover and carbon density of a given area. It is, therefore, essential to accurately determine the area and map the boundary of a forest area for carbon accounting. Satellite data provides an excellent source of information about different features of a large area at different temporal scales. Satellite Land Monitoring System (SLMS) is considered as the major component of REDD+ activities. Sentinel-2 satellite imageries of 2016 developed by European Space Agency were used in the current study. This satellite system provides the spatial information by using 13 spectral bands *(10 m. Spatial Resolution and vegetation red edge spectral bands)* for forestry and other land use practices.



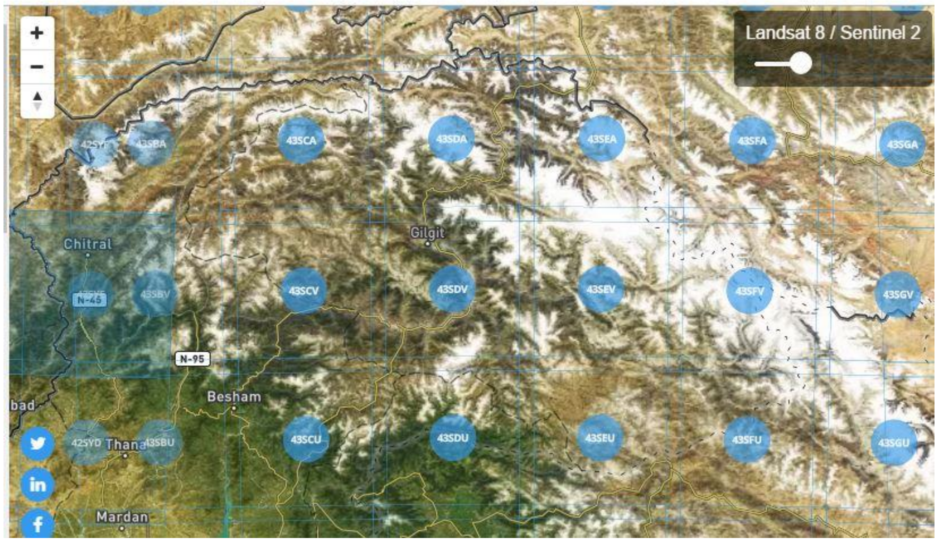
District =>			DIAMER	ASTORE	GILGIT	GHIZER	SKARDU	NAGAR	HUNZA	GHANCHE	SHIGAR	KHARMANG	Total		
IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (sq.km)	Area (sq.km)	Area (sq.km)	Area (sq.km)	Area (sq.km)	Area (sq.km)	Area (sq.km)	Area (sq.km)	Area (sq.km)	Sub- Total (sq.km)	Sub- Total (ha)	Percentage (%)
Forest land	Natural Forest	Dense Broadleaved	51.340	11.001	11.269	6.562	2.182	11.352	0.000	0.000	0.000	0.000	93.705	9370.520	0.13
		Dense Conifer	875.544	52.245	115.175	20.415	8.278	6.976	0.000	0.000	0.000	0.000	1078.632	107863.226	1.55
		Dense Mix	68.936	5.894	16.192	1.486	1.828	2.601	0.000	0.000	0.000	0.000	96.937	9693.669	0.14
		Sparse Broadleaved	176.865	50.191	30.492	8.092	2.301	10.005	1.223	0.000	2.043	0.568	281.781	28178.059	0.40
		Sparse Conifer	546.101	167.911	59.627	25.104	11.429	12.337	2.598	4.292	9.071	4.464	842.934	84293.426	1.21
		Sparse Mix	54.458	12.935	21.240	1.479	1.907	3.170	0.000	0.000	2.428	0.444	98.063	9806.259	0.14
	Sub- Total (sq.km)		**1773.244**	**300.177**	**253.995**	**63.138**	**27.925**	**46.442**	**3.821**	**4.292**	**13.542**	**5.476**	**2492.052**	**249205.159**	**3.58**
	Sub- Total (ha)		**177324.400**	**30017.746**	**25399.470**	**6313.770**	**2792.495**	**4644.160**	**382.110**	**429.237**	**1354.220**	**547.551**	**249205.159**		
	Farm Forest	Linear/Block plantations/Orch*	15.286	17.564	53.489	115.503	60.828	17.326	46.207	44.490	38.376	18.489	427.558	42755.760	0.61
Cropland	Agricultural Land	Agricultural Land	54.395	31.160	43.103	110.887	30.403	21.406	9.336	30.480	45.994	5.065	382.229	38222.930	0.55
Grassland	Pastures/ Range land	Alpine/ Summer pastures	476.934	1636.790	639.987	1132.040	1995.460	210.705	158.080	191.433	310.000	101.496	6852.925	685292.500	9.83
		Winter Pastures	942.172	560.199	426.992	464.580	126.661	126.406	217.984	153.271	231.601	31.785	3281.651	328165.070	4.71
Wetlands	Water Bodies	Rivers/ Lakes	32.300	9.911	19.224	33.219	26.738	4.736	12.815	17.723	18.460	7.381	182.507	18250.690	0.26
Settlements	Built-up Area	Settlements	2.379	3.886	27.341	10.649	13.530	0.311	3.807	3.916	3.488	1.050	70.358	7035.758	0.10
Other land	Rocks/ Barren land	Rocks/ Barren land	3470.710	2065.000	2182.860	8893.520	5214.140	1586.480	8164.670	5567.561	3306.320	2321.420	42772.681	4277268.100	61.38
	Snow/ Glacier	Snow/ Glacier	227.800	431.055	476.401	1062.370	399.054	1280.290	2920.370	3103.430	3279.550	43.324	13223.644	1322364.360	18.98
Total (sq.km)			**6995.220**	**5055.743**	**4123.392**	**11885.905**	**7894.738**	**3294.101**	**11537.090**	**9116.597**	**7247.332**	**2535.485**	**69685.603**	**6968560.327**	**100.000**
Total (ha)			**699521.977**	**505574.324**	**412339.210**	**1188590.510**	**789473.825**	**329410.096**	**1153708.956**	**911659.705**	**724733.212**	**253548.512**	**6968560.327**		

73°0'0"E 74°0'0"E 75°0'0"E 76°0'0"E 77°0'0"E

Figure 1. Landuse Map of Gilgit Baltistan

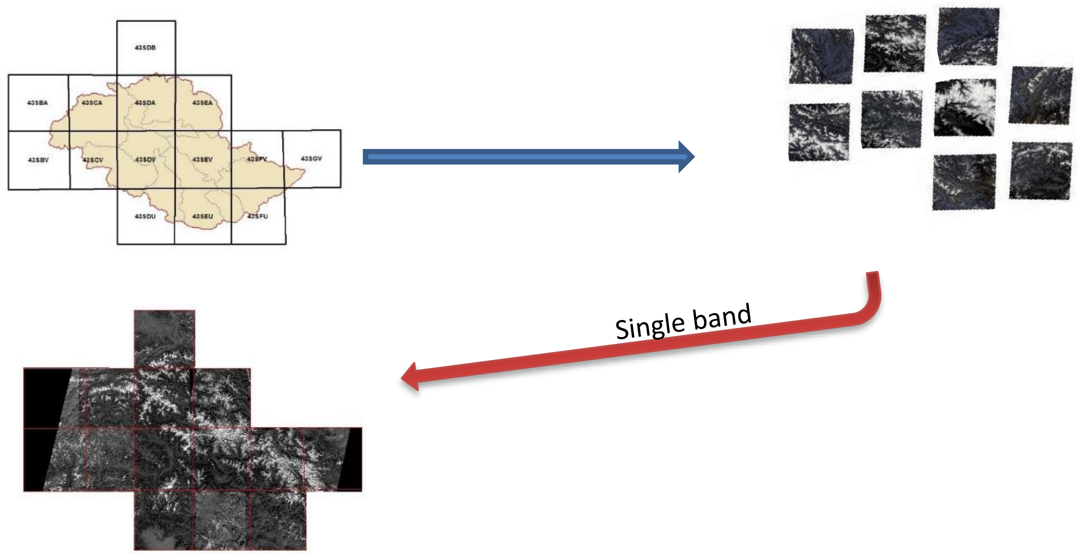
2.1.1 Data Acquisition and Preparation

The Sentinel-2 satellite system assigns the grid codes to their users to identify their area of interest. The Sentinel-2 grid codes to cover the entire Gilgit-Baltistan are; 43SBA to 43SEA, 43SBU to 43 SFV, 43SCU to 43 SFU & 43SDB.



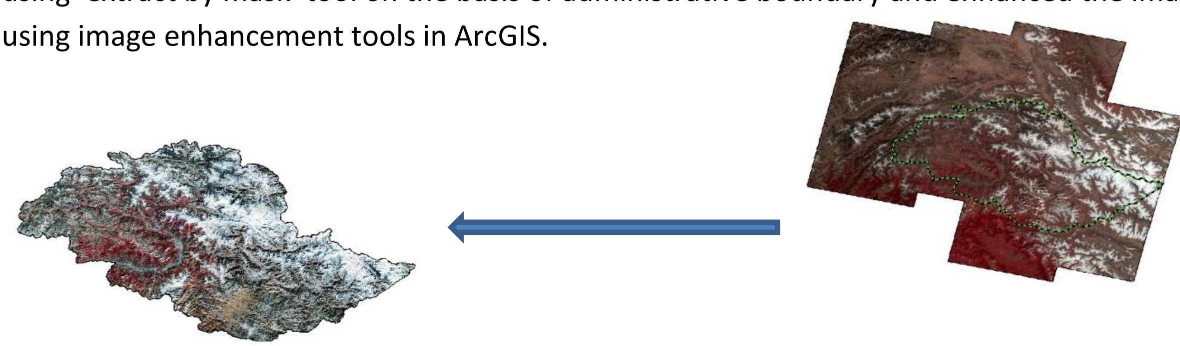
Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water vapour	0.945	60
Band 10 - SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

Satellite data was acquired in the form of scenes/ tiles & processed using image processing tools in ArcGIS. Scenes of the same band were stitched by using ‘mosaic’ tool to make a single band for the whole area of interest. The satellite image/ scenes of summer season having less than 10% of snow/ clouds cover were used in this study.



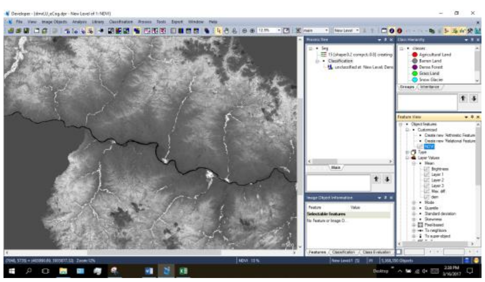
All single bands were then merged using ‘band composite’ tool to make multi-band/ multi-resolution image.

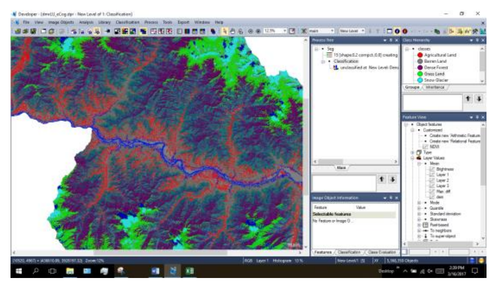
The extraction of area of interest (Gilgit-Baltistan) out of mosaicked image was carried out by using ‘extract by mask’ tool on the basis of administrative boundary and enhanced the image using image enhancement tools in ArcGIS.



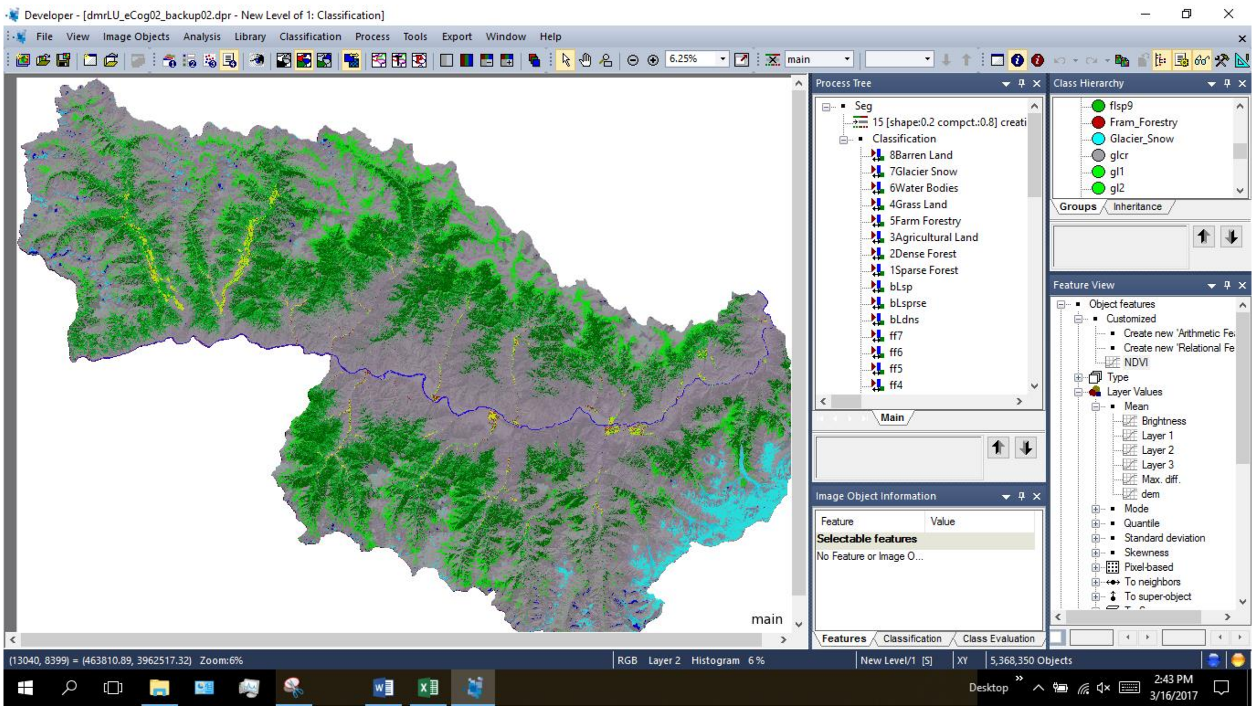
2.1.2 Image Segmentation and Classification

The land use classification was performed through a series of spatial analysis (rule set) in eCognition. Segmentation is the first step in this object based classification. In the mountainous terrain of Gilgit- Baltistan, the aspect and slope variations make the topography so hard to identify the features where most of the area comprise narrow valleys and deep gorges. The alteration in threshold values in segmentation algorithm in each district gave the fine delineated segments. The segments were then used as sample or representative in each feature class for Nearest Neighborhood Classification (NN). The sample features or signatures were taken on the basis of homogeneity of object information that involves many factors such as pixel reflectance, RS indices, ground coverage points and ground/ folk knowledge. All these factors were used for forest classification in addition to inventory sample plots to stratify forest area into six strata i.e. dense conifer, dense mixed, dense broad-leaved, sparse conifer, sparse mixed and sparse broad-leaved forests.

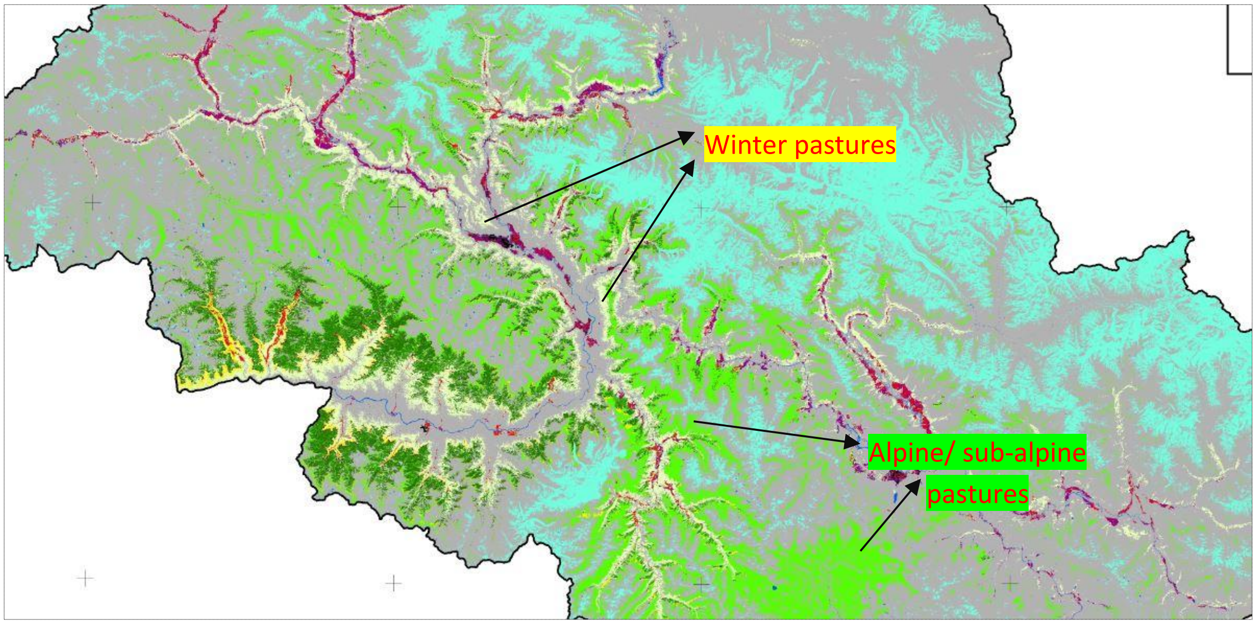




The NN classification results were then improved and bifurcated into subclasses on the basis of digital elevation model and RS indices. The ambiguities in the first hand results in classification were minimized by using query based approach on classified segments. Building quires on the basis of elevation and RS indices on feature classes helped to identify the inaccurately submerged segments in other classes and were then assigned to accurate class by querying those segments. In the first hand NN classification results, some dark shadows of non-vegetation area were classified as dense conifer forest. In fact, it has happened because of darker color shades. Thus, the segments of dark shades were identified by querying using NDVI values and were added in barren/ rocks class or dense conifers accordingly. Similarly, the shadows in glacier or snow cover was classified as water bodies, such segments were also identified using NDSI values and DEM (as snow/ glacier exists at higher elevation or above 5000 m elevation in summer) and classified as snow/ glacier accordingly. In Diamer district natural forests of broadleaved species were bifurcated into two main classes using DEM values i.e. Oak and Birch Forests. Oak forests are spread over wide area at lower elevations whereas birch forests are located on higher elevations along timber line where above alpine/ sub- alpine scrub forests are found.



In Gilgit- Baltistan, alpine and sub- alpine pastures are widely spread. These areas are subjected to grazing in summers but remain closed in rest of the seasons. So in winter cattle mostly depend on winter pastures i.e. the land sparsely covered by Artemisia at lower elevations. Winter pastures were distinguished from grasslands which fall at lower limit values of NDVI at lower elevations for vegetated land.



Farm forests including linear/ block plantations and orchards were separated from broadleaved forests using DEM and Neighborhood object to 'agricultural land' queries.

2.2 Forest Carbon Inventory

Before designing the forest inventory, relevant literature and guidelines were collected and extensively reviewed to devise a methodology in conformity with international standards. Technical support was provided by experts from ICIMOD and Pakistan Forest Institute, Peshawar. The inventory methodology consists of the following key elements.

2.2.1 Inventory Design

Stratified random sampling technique was used for collecting data in the field. This sampling design is efficient in reducing the possibility of bias, determining a valid sampling error and ensuring equitable representation of different strata in sampling. By applying this sampling technique it was possible to use already available information about the population (forest cover maps and inventory estimates) for classifying the forests into different strata (forest – non-forest, forest types and strata). This design also produced results not only for the entire forest area but also for different strata and thus helped in developing emission factors for different strata.

2.2.2 Stratification

Forest cover of Gilgit Baltistan was stratified into six strata on the basis of crown density and species composition to obtain more homogenous units for field inventory. These strata include dense conifers, dense mixed, dense broad-leaved, sparse conifers, sparse mixed and sparse broad-leaved forests. These strata were mapped through classification of satellite data and inventoried during ground measurements. These strata are further described in the flowing lines.

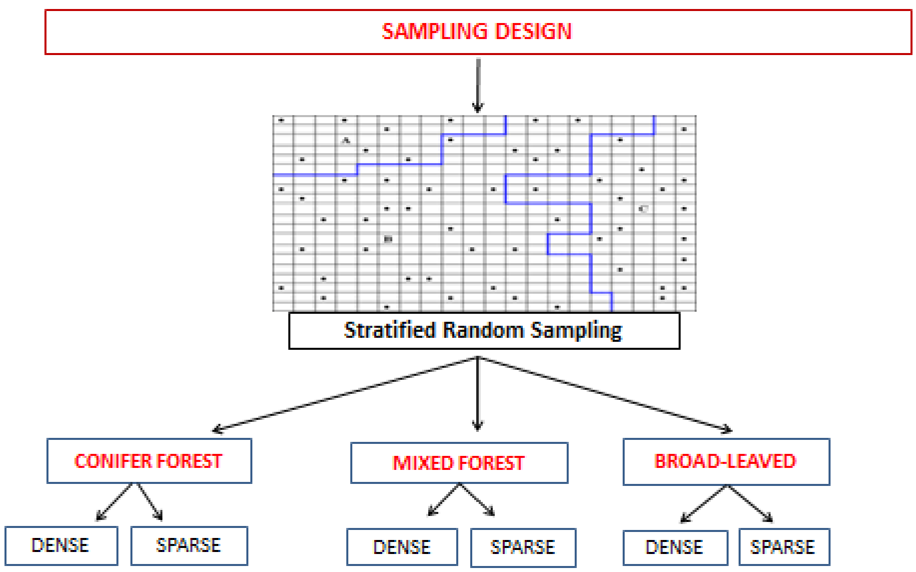


Figure 2. Schematic Presentation of Stratification

i) Pure Dense Conifers

This stratum consists of more than 80% coniferous trees having crown density of more than 35%. Major tree species included Deodar, Kail, Fir, Spruce, Chilghoza, Juniper and Taxus. This strata may have oak and birch but less than 20% of the stand. This strata occurred at altitude between 2150-3650 m asl.

ii) Dense Mixed Forests

This strata comprises both conifers and broad-leaved species mixed in different proportion with crown density above 35%. Coniferous species included Deodar, Kail, Fir, Spruce, Chilghoza and Juniper. Broad-Leaved Species included Oak and Birch. These forests are located between 1950-3700 m asl.

iii) Dense Pure Broad-leaved Forests

This class consists of more than 80% broad-leaved trees having crown density of more than 35%. Main species found in this class are oak and birch. This strata is found at altitude of 1800-3900 m asl.

iv) Sparse Conifers

This stratum consists of more than 80% coniferous trees with crown density less than 35%. Major tree species included Deodar, Kail, Fir, Spruce, Chilghoza, Juniper and Taxus. This stratum may have oak and birch but less than 20% of the stand. This stratum occurred at altitude between 2100-3980 m asl.

v) Sparse Mixed Forests

This stratum comprises both conifers and broad-leaved species mixed in different proportion with crown density less than 35%. Coniferous species included Deodar, Kail, Fir, Spruce, Chilghoza and Juniper. Broad-Leaved Species included Oak and Birch. These forest are found in the elevation zone of 1950-3800 asl.

vi) Sparse Pure Broad-leaved Forests

This class consists of more than 80% broad-leaved trees having crown density of less than 35%. Main species found in this class are oak and birch. This stratum is located between 1750-3800 m asl.

2.2.3 Field Work

Field work was carried out during 2015-2016. A field party was constituted for the inventory comprising a team leader (a sub-divisional forest officer, a forest ranger, a GIS Specialist, a forester and a helper. Before start of the field work, the team was properly trained for the field work and acquainted with the objectives of the inventory.

2.2.4 Field Measurements

As the current inventory was aimed at estimating biomass and carbon stock only in the aboveground biomass pool, fixed area circular sample plot with area was used. Circular shape plot was preferred due to easiness in laying out in the hilly area. The circular plot of 17.84 m radius (0.1 ha) was used for measuring the attributes of all trees with Diameter at Breast Height (DBH) ≥ 5cm. In most of the cases, the plots were laid out with the help of Vertex Hypsometer which automatically corrects slope of the radius. However, in some cases ordinary tape was used for plot delineation wherein slope correction factor was applied. Diameter at Breast Height (DBH) was measured with dia tape at 1.37 m above ground on uphill side. Heights of trees were measured through Vertex Hypsometer. Crown diameters of the trees were also recorded. Above-ground Tree Biomass (AGTB) was calculated through locally developed allometric equations for major tree species. However for minor tree species the equations available in literature were used. Trees less than 5 cm were only counted in the circular plots.

2.2.5 General Parameters Recorded

The following parameters were measured at each sample plot location:

- Date
- Name of District and Forest Area
- Forest Type and subtype
- Stand Composition

- GPS Coordinates
- Elevation
- Slope
- Aspect
- Crown cover

2.2.6 Sample Size

As mentioned earlier, stratified random sampling design was used in this study, sample size was determined for different strata using the following formula:

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

Where

N= Number of required sample plots

CV= Coefficient of Variation

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

E= Allowable Error

CV was determined on the basis of data collected from 26 plots during a pilot survey in the forest areas of Gilgit Baltistan. Based on pilot survey, CV was determined as 89. The number of the required sample plots was calculated as follows:

$$N= \frac{(89)^2 x 1.96^2}{10^2} = 304$$

Thus a total of 304 plots were required for the given sampling precision.

Later on when the results of the inventory were analyzed it was found that there are large variations in strata other than dense coniferous forests, thus additional sample plots were measured in these strata. The total number of sample plots measured was 537.

2.2.7 Laying out of sample plots on the map

The sample plots were assigned to different strata randomly using GIS software. The distribution of sample plots in different forest areas is shown in Figure 3. The coordinates of the centers of the sample plots were noted from the geo-referenced maps. The coordinates were uploaded onto GPS and navigated in the field accordingly.

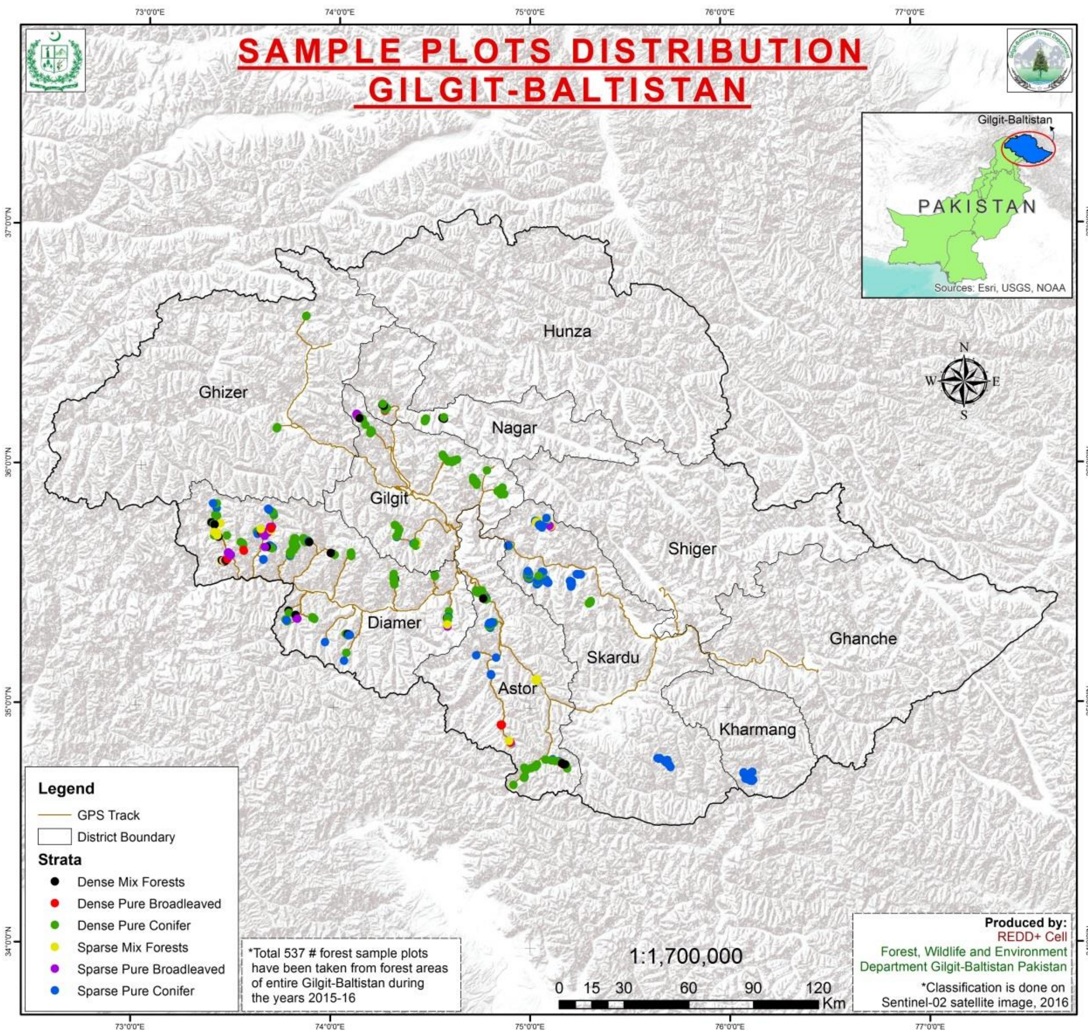


Figure 3. Distribution of Sample Plots

2.2.8 Distribution of Sample Plots in different forest types/strata

A total of 537 sample plots were laid out in different forest strata for data collection. About 53% of the total sample plots were falling in dense forests and 47% were in sparse forests. In dense coniferous forests have highest number of sample plots (45%) followed by sparse conifers (33%). Similarly, dense mixed and dense broad-leaved forests have 5.4% and 3.35%

sample plots whereas sparse mix and sparse broad-leaved forests have 7.455 and 6.15% sample plots respectively. The distribution sample plots in different forest strata are given in Table 1.

Table 1. Distribution of Sample Pots in different Forest strata

Forest Type/Strata	**Number of Sample Plots**	**% of Sample Plots**
Dense Conifer	240	44.69
Dense Mix	29	5.40
Dense Broadleaved	18	3.35
Sparse Conifer	177	32.96
Sparse Mix	40	7.45
Sparse Broadleaved	33	6.15
Total	**537**	**100**

2.2.9 District-wise Distribution of Sample Plots

Forest area is unevenly distributed in the different districts of Gilgit Baltistan. Thus, sample plots were distributed in different districts in proportion to their respective forest area except Skardu where the number of sample plots were higher than its share in the total forest area. Out of the total 537 sample plots, 33% were located in Diamer district followed by Skardu where 32% sample plots were laid out. Similarly 18% plots were falling in the boundaries of Astore District. Gilgit district has 12% of the total sample plots whereas Nagar, Ghizer and Kharmang have 3%, 1% and 0.7% sample plots respectively (Table 2).

Table 2. District-wise Distribution of Sample Plots

District	**No. of Sample Plots**	**%age**
Diamer	178	33.15
Astore	99	18.44
Gilgit	62	11.55
Skardu	173	32.22
Nagar	16	2.98
Ghizer	5	0.93
Kharmang	4	0.74
Total	**537**	**100**

2.2.10 Distribution of Sample plots on different aspects

The sample plots were amply representing all aspects of the forest landscape. About 19% of sample plots were located on northern aspect and 10% were located on southern aspects. About 16% plots were representing north east aspect and 12% were representing north western aspect. Similarly, about 14% sample plots were on south western aspect and 7% were on south eastern aspect. On the other hand, 4% of the sample plots were on eastern and 17% were on western aspects (Table 3). It is well established that northern aspect is relatively cooler and moist than the southern aspect which has more exposure to sunlight in Gilgit Baltistan.

Table 3. Aspect-wise distribution of sample plots

Aspect	%age of Sample Plots
East	4.13
North	18.73
North East	15.98
North West	12.40
South	10.47
South East	7.44
South West	13.50
West	17.36

2.2.11 Distribution of Sample plots in different elevation ranges

The altitude of sample plots ranged from 1808 to 3963 m. About 97% of the sample plots were located in high hill forests. About 61% of sample plots were located in the elevation zone 3000-4000 m, 36% were in elevation zone 2000-3000 m and only 2.5% were in elevation below 2000 m (Figure 4). In terms of forest types, 65% of the sample plots were located in temperate (1800-3300m) and 35% were in sub-alpine forests (above 3300m).

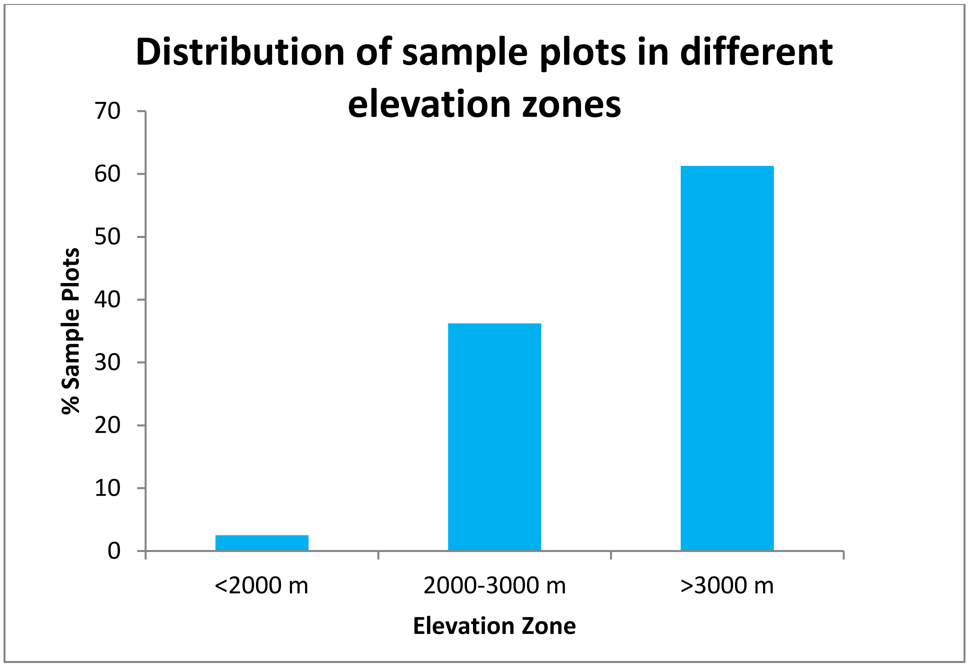


Figure 4. Distribution of Sample Plots in different elevation zones

2.3 Development of Local allometric models for biomass and carbon estimation

The accuracy of carbon estimates depends on the availability of reliable allometric models to infer biomass and subsequent carbon stock of trees from forest inventory data. As the use of generalized equations can lead to a bias in biomass and carbon estimation (Cairns *et al.,* 2003, Chave *et al.,* 2005; Litton, 2008), it is suggested to develop species specific models for accurate estimation of biomass and carbon. It was, therefore, decided to develop local allometric models for major tree species of Gilgit Baltistan to accurately estimate carbon stock in the forests. These models were developed through destructive sampling which involved felling and weighing of sample trees in the forests and subsequent drying of wood and foliage samples in the oven till constant weight to derive oven dry biomass for whole trees. The detail methodology used for development of these allometric models is given by Ali (2015). The allometric equations developed under the current project are given in Table 4. Allometric models, biomass expansion factors and basic wood densities were determined for the following tree species.

- Deodar (*Cedrus deodara*)
- Kail (*Pinus wallichiana*)
- Fir (*Abies pindrow*)

- Spruce (*Picea smithiana*)
- Chilghoza (*Pinus gerardiana*)
- Oak (*Quercus ilex*)

Table 4. Local allometric equations for biomass estimation

Species	**Regression Model**	**Allometric equation**
General (Coniferous species)	$M = a(pD^2H)^b$	$M = 0.1645(pD^2H)^{0.8586}$
Cedrus deodara (Deodar)	$M = a(D^2H)^b$	$M = 0.1779(D^2H)^{0.8103}$
Pinus wallichiana (Kail)	$M = a(D^2H)^b$	$M = 0.0631(D^2H)^{0.8798}$
Pinus gerardiana (Chilghoza)	$M = aD^b$	$M = 0.0253D^{2.6077}$
Abies pindrow (Fir)	$M = a(D^2H)^b$	$M = 0.0954(D^2H)^{0.8114}$
Picea smithiana (Spruce)	$M = a(D^2H)^b$	$M = 0.0843(D^2H)^{0.8472}$
Quercus ilex (Oak)	$M = a(D^2H)^b$	$M = 0.8277(D^2H)^{0.6655}$

M= Biomass in Kg, p= Basic Wood Density, D= Diameter at Breast Height in cm, H=Height in meters

3. Results

3.1 Total Forest Area

Different agencies have reported different estimates of forest area in Gilgit Baltistan. Forestry Sector Master Plan (1992) estimated the total forest area of Gilgit Baltistan as 660,000 ha on the basis of visual interpretation of satellite imageries of Landsat TM having 30 m resolution. Later on, National Forest and Range Resource Assessment Study (2004) estimated the forest area of Gilgit Baltistan as 320,000 ha.

Recently, PFI prepared a Land cover Atlas for Pakistan which estimated the forest area of Gilgit Baltistan as 337,491 ha based on visual interpretation of spot-5 imageries having 2.5 m resolution. ICIMOD estimated the total forest area of Gilgit Baltistan as 157,233 ha through Object Based Classification of Landsat imageries (30 m) of 2010.

The current study estimated the forest area of Gilgit Baltistan as 249,205 ha which make up 3.57% of the total area of the region.

The estimates of forest area produced by different studies are given in Table 5.

Table 5. Estimates of Forest Cover of Gilgit Baltistan by different studies

S.No	Name of Study	Year	Forest Area Reported (ha)
1	Forestry Sector Master Plan	1992	660,000
2	National Forest and Range Resource Assessment Study (including FATA)	2004	320,000
4	Landcover Dynamics of Pakistan (ICIMOD)	2010	157,233
6	Landcover Atlas of Pakistan	2012	337,491
7	**Current Study**	**2017**	**249,205**

3.2 Distribution of forest area in different districts

Gilgit-Baltistan comprises of 10 districts. Diamer has the highest forest cover (71%) followed by Astore (12%) and Gilgit (10%). These three districts together contain 93% of the total forest area of Gilgit Baltistan. Ghizer, Nagar and Skardu districts have 2.5%, 1.86% and 1.12% forest area respectively. The district-wise distribution of forest area is given in Table 6.

Table 6. District wise Distribution of forest area

District	Forest Area	%age
Diamer	177,324	71.16
Astore	30,018	12.05
Gilgit	25,399	10.19
Ghizer	6,314	2.53
Nager	4,644	1.86
Skardu	2,793	1.12
Hunza	382	0.15
Ghanche	429	0.17
Shiger	1,354	0.54
Kharmang	548	0.22
Total	**249,205**	**100**

3.3 Distribution of forest area on the basis of crown density

On the basis of crown density, the forests were classified into dense and sparse forests determined through interpretation of satellite imageries. It was found that about 51 % (126,927 ha) of the forest are dense forests which have canopy cover of more than 35%. On the other hand about 49% (122,277 ha) are sparse forests which have crown density of less than 35% as shown in Figure 5.

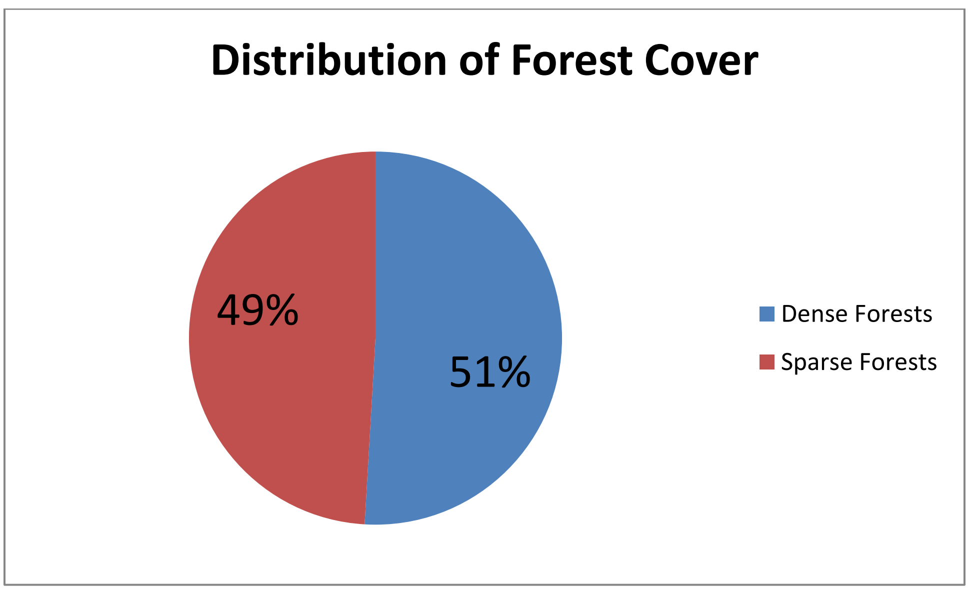


Figure 5. Distribution of forest area on the basis of crown density

Table 7. District-wise Distribution of forest strata

District	Dense Forest (ha)	% age	Sparse Forest (ha)	% age
Diamer	99582	56.16	77742	43.84
Astore	6914	23.03	23104	76.97
Gilgit	14263	56.16	11136	43.84
Ghizer	2846	45.07	3468	54.93
Skardu	1228	43.97	1565	56.03
Nager	2093	45.07	2551	54.93
Hunza	-	-	382	100.00
Ghanche	-	-	429	100.00
Shiger	-	-	1354	100.00
Kharmang	-	-	548	100.00

3.4 Distribution of Forest Area into different strata

Forest area was classified into different forest strata on the basis of crown density and species composition. It was found that the highest amount of forest cover falls under the dense coniferous class (43%) followed by sparse conifers (34%) and sparse broad-leaved forest (11%). The remaining forest cover consists of dense mix, dense broad-leaved and sparse mixed forests each having 4% cover as shown in Figure 6.

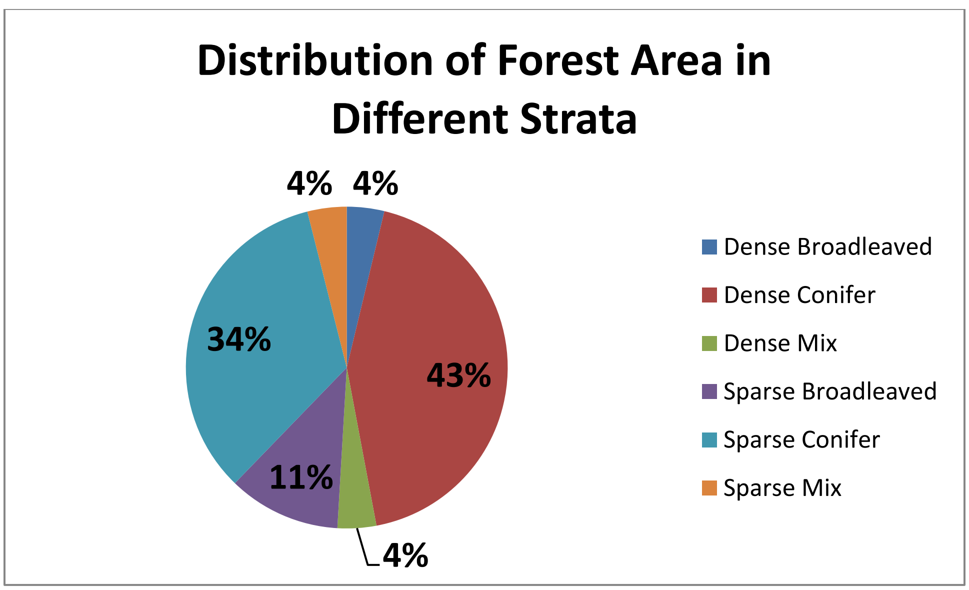


Figure 6. Distribution of Forest Area into Forest strata

Table 8. Distribution of Forest Area into Forest strata

Forest Strata	***Area (ha)***	**%age**
Dense Broadleaved	*9370.5*	3.76
Dense Conifer	*107863.2*	43.28
Dense Mix	*9693.7*	3.89
Sparse Broadleaved	*28178.1*	11.31
Sparse Conifer	*84293.4*	33.82
Sparse Mix	*9806.3*	3.94
Total	**249205.2**	**100**

3.5 Growing Stock Composition

A total of 13,135 trees belonging to 9 different species were tallied during the field measurements. The tree species sampled predominantly consisted of conifers (78%) with few broadleaved species (22%) as shown in Figure 7. Deodar (*Cedrus deodara*) is the dominant specie (23%) followed by Kail (*Pinus wallichiana*) with 22% and Spruce (Picea smithiana) with 20% share in the total growing stock. Fir (*Abies pindrow*) has 7% share in the total trees. Thus, 72% of the total growing stock consists of these four species. Juniper and Chilghoza have small proportions in total number of trees with 2.34% and 2.84% shares, respectively. Oak (*Quercus spp.*) is the dominant broad-leaved species recorded during the inventory with 15.31% followed by *Betula utilis* (Birch) with 6.98% contribution in the total trees. *Taxus wallichiana* (Yew) has only 0.21% share in the total trees sampled during the inventory (Table 9). Thus, it is clear from the data that the forests of Gilgit Baltistan have relatively less diversity of tree species. About 78% of the total growing stock consists of conifers and only 22% are broad-leaved species.

Table 9. Frequency of Tree Species

Species	**%age**
Birch	6.98
Chilghoza	2.84
Deodar	23.14
Fir	7.45
Juniper	2.34
Kail	22.05
Oak	15.31
Spruce	19.67
Yew	0.21

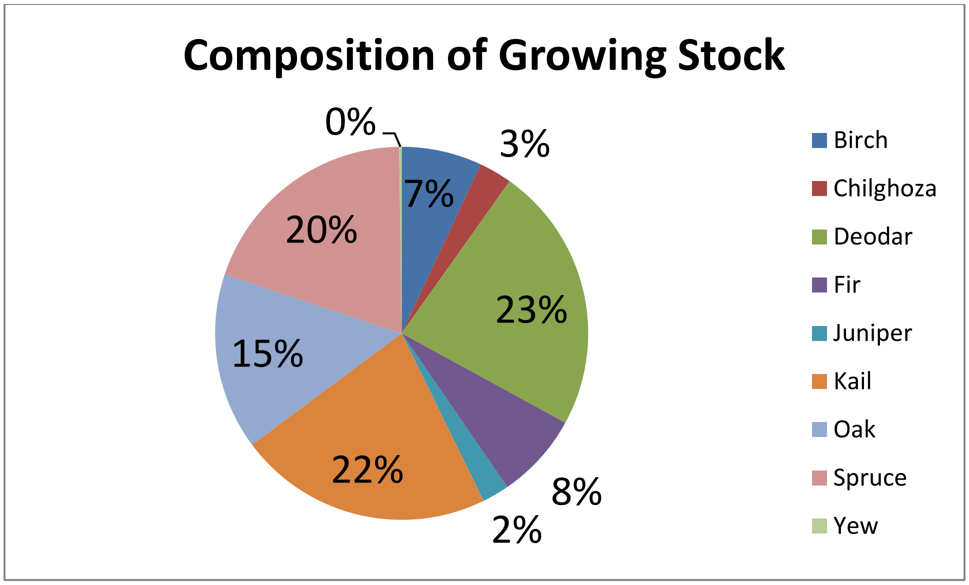


Figure 7. Frequency of Tree Species

3.6 Tree Stocking/Density

The average stocking/density was estimated at 244 trees per ha. In dense and sparse forests, the average number of trees per ha were estimated at 356 and 111 respectively. Highest number of trees per unit area was found in Dense Pure Broad-Leaved Forest i.e. 660 trees/ha, followed by Dense Mixed forests with 405 trees/ha. This was probably due to multi-stemmed habit of oak and Birch which are dominant in these two strata. Secondly comparatively more protection is provided to oak forests by local communities due to which their density is high. Similarly dense pure coniferous forests have density of 332 trees/ha. On the other hand, Sparse pure Broad-leaved forests have 190 trees/ha, followed by sparse mixed forests 140 trees/ha and sparse pure conifers have 89 trees/ha. The detail is given in the Table 10.

Table 10. Tree Stocking/Density

S.No	Forest Type	No of trees/ha
1	Dense Mixed	405
2	Dense Pure BL	660
3	Dense Pure Conifer	332
4	Sparse Mixed	140
5	Sparse Pure BL	190
6	Sparse Pure Conifer	89
Overall Average		**244**

3.7 Diameter Class Distribution

Diameter class distribution of the trees sampled during the inventory is given in Table 11 and shown in Figure 8. It is evident from the diagram that dia-class distribution follows a left-skewed trend indicating that most of the trees are young and hence fall in immature dia-classes. Highest number of trees are distributed in dia classes less than 21 cm. Next higher number is in dia class 21-30. These three classes are considered as young or immature crop. Thus majority of the trees (66%) are immature. Very low proportions of trees are present in dia class 60 cm and above.

Table 11. Diameter Class Distribution

Dia-class	No of Sample Trees	% of sample trees
<11	2256	17.18
11--20	3727	28.37
21-30	2561	19.50
31-40	1812	13.80
41-50	1193	9.08
51-60	611	4.65
61-70	432	3.29
71-80	259	1.97
81-90	133	1.01
91-100	72	0.55
>100	79	0.60
Total	13135	100

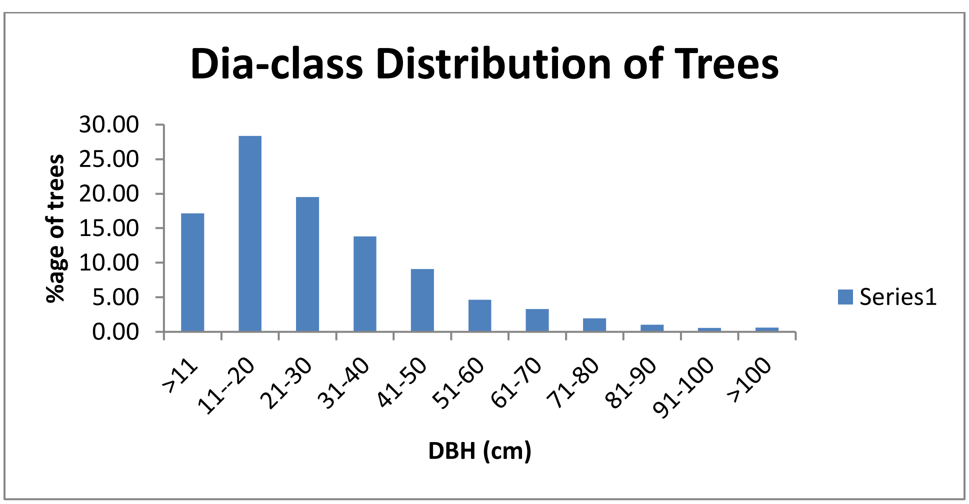


Figure 8. Diameter class distribution of sample trees

3.8 Stand Structure

The results of the inventory indicate that the forests of Gilgit Baltistan are mostly young as shown in Figure 9. About 65% of the trees fall in immature class followed by sub-mature with 27.5% sample trees. Thus about 93% of the trees are young and only 7 % of the sample trees are mature. Higher numbers of trees in the younger classes have very high potential for carbon sequestration as growth rate is generally fast in these stages and they can sequester a large amount of carbon dioxide from the atmosphere. Thus, the forests of Gilgit Baltistan have high potential for REDD+.

Table 12. Stand Structure

Development Stage	No of trees	%age
Young (<30 cm)	8544	65.04758
Sub-mature (30-60 cm)	3616	27.5295
Mature (>60 cm)	975	7.422916
Total	22521	100

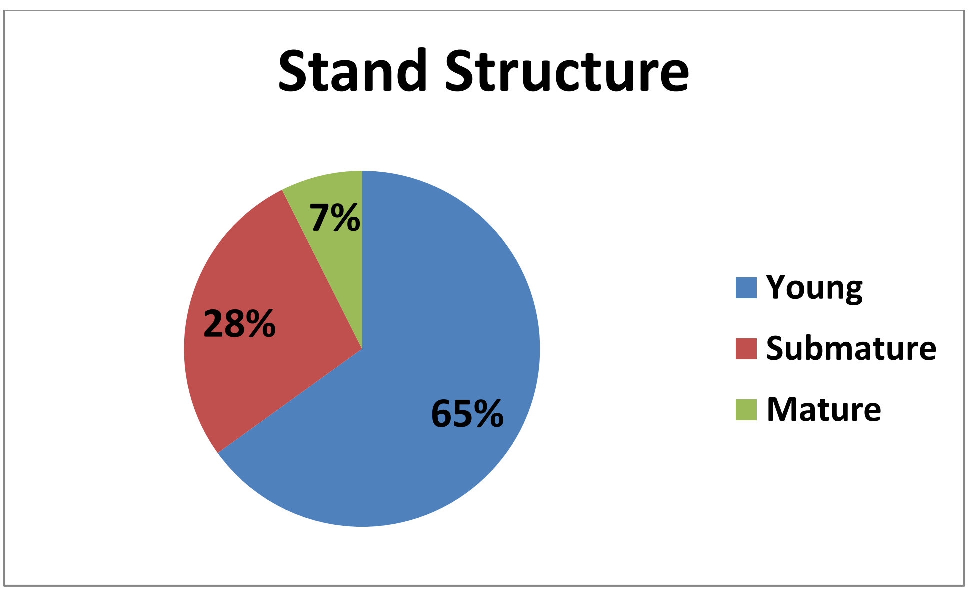


Figure 9. Stand Structure

3.9 Development stages of coniferous species

The developmental stages of coniferous species are shown in the Figure 10. Most of the trees fall in young and sub-mature stages in all coniferous species. Highest percentage of mature trees are present in spruce (12.77%) followed by deodar (11.96%). Fir and Kail have same percentage of mature trees i.e 7.3% each. Juniper and Chilghoza are predominantly young and submature with only 2.5 and 1.8% mature trees. The detail is given in table 13.

Table 13. Developmental Stages of Coniferous Species

Species	Young	Sub-mature	Mature
Deodar	57.87764	30.15701	11.96535
Kail	61.25443	31.41123	7.334345
Fir	59.91707	32.68832	7.39461
Spruce	56.61456	30.6138	12.77164
Chilghoza	66.52542	30.9322	2.542373
Juniper	82.3741	15.82734	1.798561

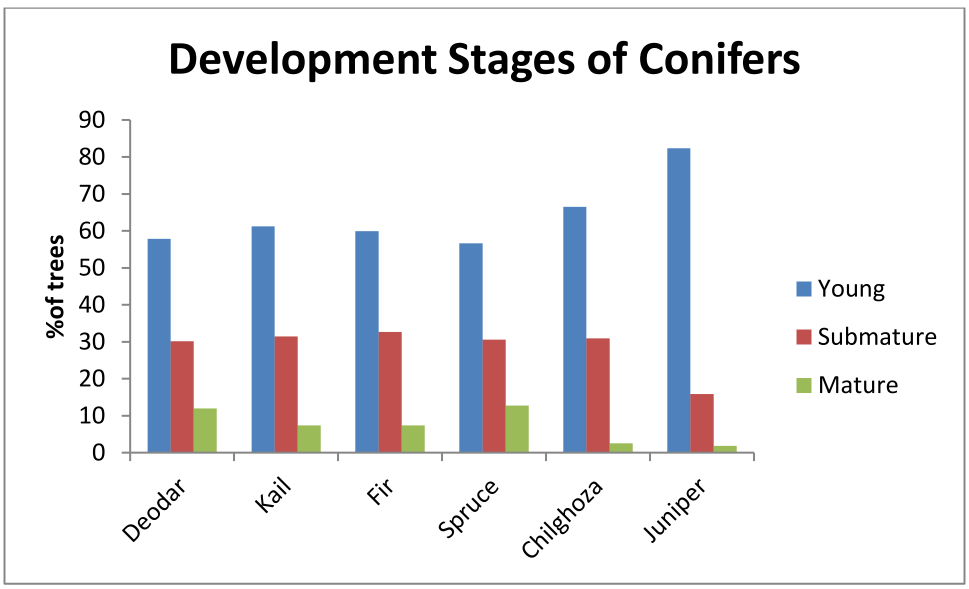


Figure 10. Development stages of coniferous species

3.10 Total Carbon Stock

Carbon stock was measured in aboveground biomass directly and belowground biomass was estimated using root-shoot ratios provided by IPCC (2006). Other carbon pools were not included in the current carbon inventory. The total carbon stock in aboveground and belowground biomass in the forests of Gilgit-Baltistan was estimated at 16.95 million ton. It was found that 80% of the carbon stock is in aboveground and 20% is in belowground pool. The highest amount of carbon stock is present in Dense Conifers (70%) followed by Sparse Conifers (14%). Dense Mixed forests have 5% share in the total carbon stock. Dense Broad-leaved and Sparse Broad-leaved forests have almost equal share in the total carbon stock i.e. 4.37% and 4.55% respectively. Similarly, sparse mixed forests have 2.09% share in the total carbon stock in the area (Figure 11).

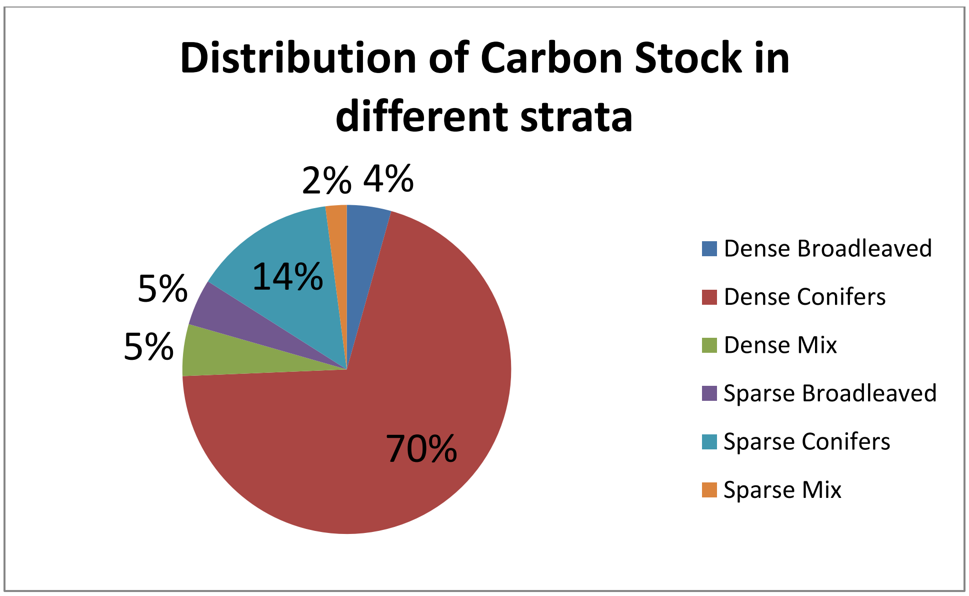


Figure 11. Distribution of carbon stock in different forest strata

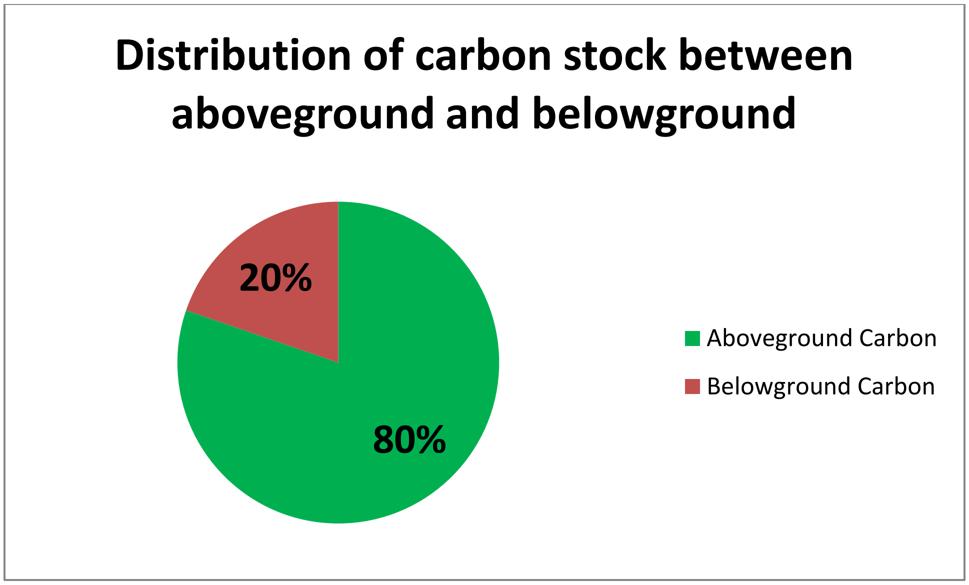


Figure 12. Distribution of carbon stock in different pools

Table 14. Distribution of carbon stock in above and belowground biomass pools and strata

Forest Strata	**Area (ha)**	**Carbon Stock (t/ha)**	**AGC (ton)**	**BGC (ton)**	**Total Carbon Stock (ton)**
Dense Broadleaved	*9370.5*	79.01	569539	170,862	**740,401**
Dense Conifer	*107863.2*	109.98	9885662	1,977,132	**11,862,794**
Dense Mix	*9693.7*	88.97	668574.489	193,874	**862,448**
Sparse Broadleaved	*28178.1*	27.36	528058	242,907	**770,965**
Sparse Conifer	*84293.4*	28	1685868	674,347	**2,360,215**
Sparse Mix	*9806.3*	36.08	252708	101,083	**353,791**
Total	**249205.2**	**68.02**	**13,590,409**	**3,360,205**	**16,950,614**

3.11 District-wise Distribution of Carbon stock

District-wise carbon stocks were calculated by multiplying forest area of the respective district with average carbon density of the forest strata. The resultant estimates are presented in Table 15. The highest amount of carbon is present in Diamer (76%), followed by Gilgit (11%), and Astore (8%) as shown in Figure 13. Thus these three districts contain 93% of the total carbon stock of Gilgit Baltistan. The remaining 7% carbon stock is distributed in Ghizer (2.3%), Nagar (1.5%), Skardu (1%), Shiger (0.23%), Kharmang (0.17%), Ghanche (0.07%) and Hunza (0.06%). It may be noted here that these estimates comprises carbon stocks in only aboveground and below ground biomass. Other carbon pools were not measured during the current inventory.

Table 15. Distribution of Carbon stock in Forest Regions and Districts

District	Dense BL	Dense Conifers	Dense Mix	Sparse BL	Sparse Conifers	Sparse Mix	Total
DIAMER	405636.5	9629233	613323.6	483902.4	1529083	196485.2	**12857663**
ASTORE	86920.48	574591.6	52436.78	137323.7	470150.8	46669.48	**1368093**
GILGIT	89034.79	1266695	144060.2	83424.74	166955.6	76635.36	**1826805**
GHIZER	51845.57	224518.7	13217.38	22140.53	70292.32	5336.232	**387350.7**
SKARDU	17236.03	91038.69	16264.07	6296.001	32002.04	6881.142	**169718**
NAGAR	89691.36	76721.06	23143.68	27373.95	34543.88	11438.44	**262912.4**
HUNZA				3346.949	7273.84		**10620.79**
GHANCHE					12018.44		**12018.44**
SHIGAR				5589.922	25397.96	8761.667	**39749.55**
KHARMANG				1553.501	25397.96	1602.313	**28553.77**
Total	**740364.8**	**11862798**	**862445.7**	**770951.6**	**2373116**	**353809.8**	**16,963,485**

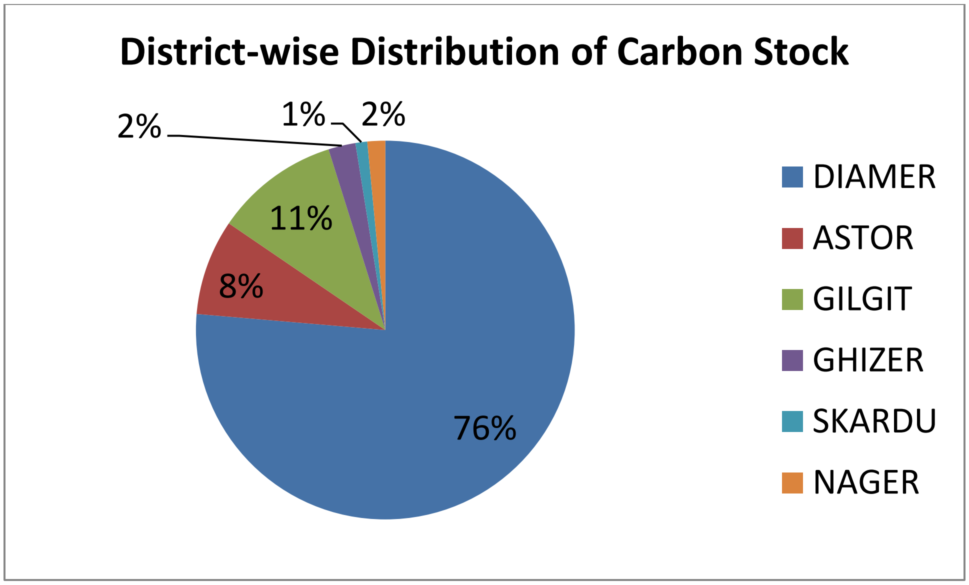


Figure 13. District-wise distribution of carbon stock

3.12 Aboveground Biomass and Carbon Stock

The aboveground biomass is the most important pool of carbon in a forest ecosystem as it is subjected to changes due to anthropogenic activities. Other carbon pools are directly or indirectly dependent on aboveground biomass. The above ground carbon stock in the forests of Gilgit Baltistan was estimated at 13,590,410 ton. Weighted mean carbon stock was calculated at 54.53 ± 3.80 t/ha and weighted average sample error was determined as 6.97% (95% confidence interval).

It was found that 84% of the total aboveground carbon is present in dense forests whereas only 16% carbon is present in sparse forests. In dense forest, the above ground carbon stock was calculated at 87.43 t/ha ranging from 1.129 t/ha to 333.493 t/ha. On the other hand, in sparse forests, the aboveground carbon stock was 20.75 t/ha ranging from 0.069 t/ha to 155.165 t/ha. The highest carbon stock was found in dense coniferous forests as 91.65 t/ha, followed by dense mixed forest as 68.97 t/ha and dense broad-leaved as 60.78 t/ha. Similarly, in sparse conifers, sparse broad-leaved and sparse mixed forests, the aboveground carbon stocks were 20.00 t/ha, 18.74 and 25.77 t/ha respectively (Figure 14). The statistical analysis of the carbon stock estimates is given in Table 17.

Table 16.Distribution of aboveground carbon stock

Forest Strata	Area (ha)	AGC (t/ha)	Total AGC (ton)
Dense Broadleaved	*9370.5*	60.78	569539
Dense Conifer	*107863.2*	91.65	9885662
Dense Mix	*9693.7*	68.97	668574
Sparse Broadleaved	*28178.1*	18.74	528058
Sparse Conifer	*84293.4*	20.00	1685868
Sparse Mix	*9806.3*	25.77	252708
Total	249205.2		13,590,410

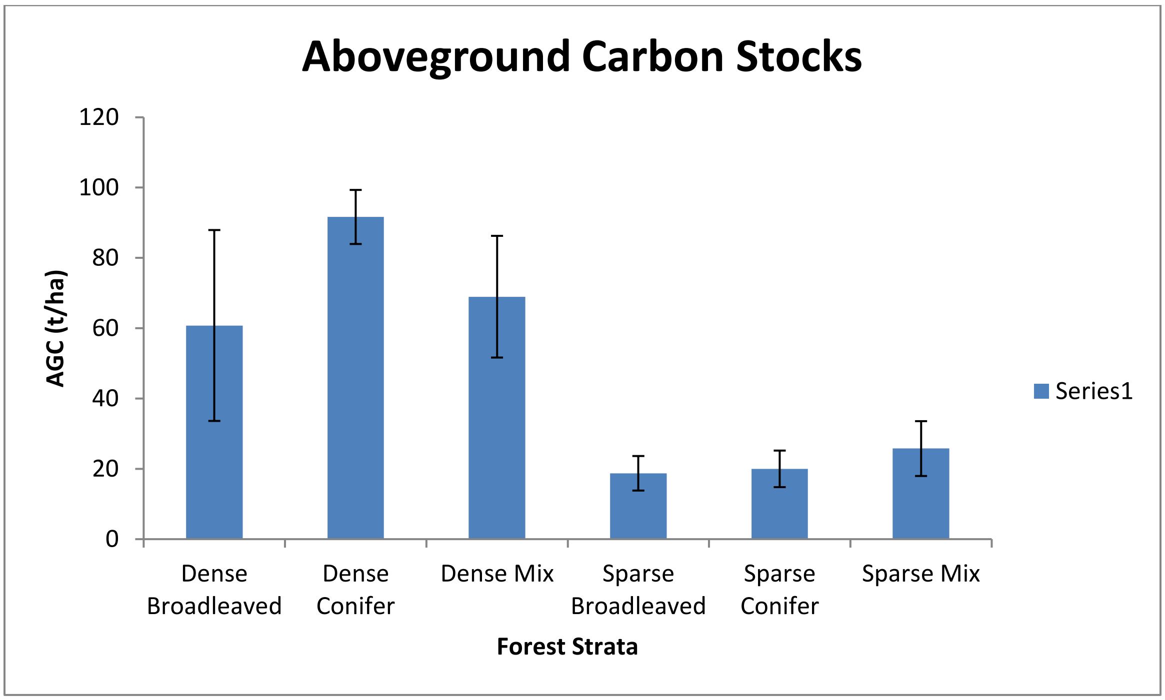


Figure 14. Aboveground carbon stock in different forest strata

Table 17. Statistics regarding above ground carbon stock in different forest strata

Statistic	Dense Mix	Dense Broad-Leaved	Dense Conifer	Sparse Mix	Sparse Broad-Leaved	Sparse Conifers
Number of Sample Plots (N)	29	18	240	40	33	177
Mean (t/ha)	68.97	60.78	91.65	25.77	18.74	20.00
SD	46.61	57.59	59.60	24.68	14.11	34.57
CV	67.58	94.75	65.03	95.77	75.29	172.88
Standard Error	8.66	13.57	3.85	3.90	2.46	2.60
Relative Standard Error	12.55	22.33	4.20	15.14	13.11	12.99
Sampling Error (t/ha)	17.31	27.15	7.69	7.80	4.91	5.20
Sampling Error%	25.10	44.67	8.40	30.28	26.21	25.99

Table 18. Statistics regarding overall mean carbon stock

Forest Type	Forest Area (ha)	% of area	Mean AGC (t/ha)	Weighted Mean AGC (t/ha)	SD	Weighted SD	N	SE	Sampling Error (t/ha)	Sampling Error%
Dense Broadleaved	*9370.5*	3.76	60.78	2.285422	57.59	2.165473	18			
Dense Conifer	*107863.2*	43.28	91.65	39.66876	59.6	25.7966	240			
Dense Mix	*9693.7*	3.89	68.97	2.682827	46.61	1.813058	29			
Sparse Broadleaved	*28178.1*	11.31	18.74	2.118967	14.11	1.595444	33			
Sparse Conifer	*84293.4*	33.82	20	6.764979	34.57	11.69327	177			
Sparse Mix	*9806.3*	3.94	25.77	1.014057	24.68	0.971165	40			
Total	249205.2			54.53502		44.03501	537	1.90	3.80	6.97

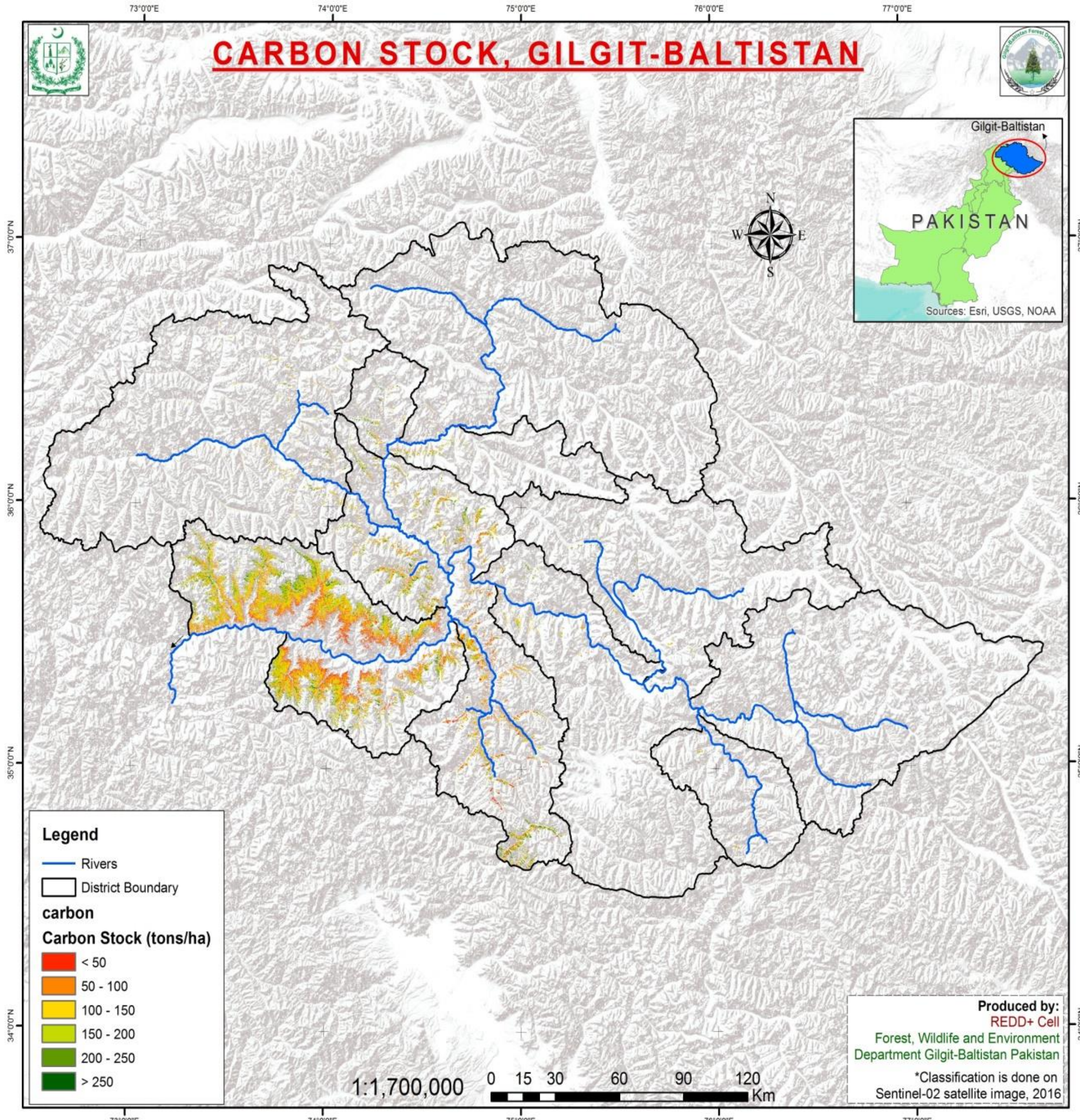


Figure 15. Map of Aboveground Carbon in Gilgit Baltistan

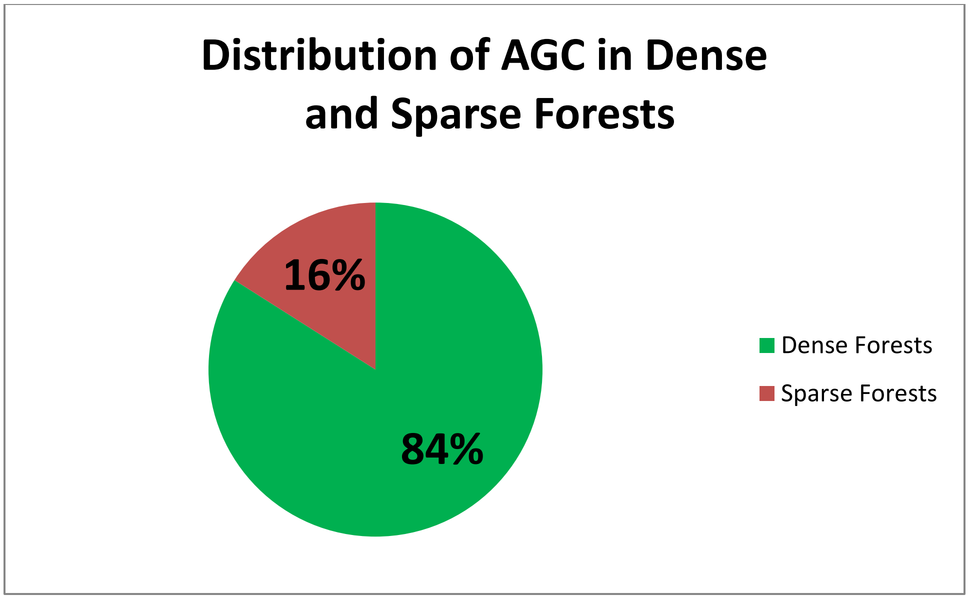


Figure 16. Distribution of Aboveground carbon between dense and sparse forests

3.13 Belowground Biomass

Belowground biomass was derived from the aboveground biomass using the root-shoot ratios provided by IPCC (2006). The total carbon stock in belowground biomass of the forests of Gilgit Baltistan was estimated at 3.36 million ton. Estimates of belowground carbon in different forest strata are given in the Table 19.

Table 19. Belowground carbon in different forest strata

Forest Strata	Area (ha)	AGC (t/ha)	Root:Shoot Ratio	BGC (t/ha)	Total BGC (ton)
Dense Broadleaved	*9370.5*	60.78	0.30	18.23	170861.7
Dense Conifer	*107863.2*	91.65	0.20	18.33	1977132
Dense Mix	*9693.7*	68.97	0.29	20.00	193886.6
Sparse Broadleaved	*28178.1*	18.74	0.46	8.62	242906.5
Sparse Conifer	*84293.4*	20	0.40	8.00	674347.2
Sparse Mix	*9806.3*	25.77	0.40	10.31	101083.3
Total	249205.2				3,360,218

3.14 Annual Carbon Sequestration

Annual carbon sequestration was estimated using the growth rate of the forests. According to IPCC (2006), the growth rate (dry matter) of temperate forests is 3.0 t/ha which is equivalent to carbon sequestration of 5.15 ton CO_2/ha. Thus, it is calculated that the forests of Gilgit-Baltistan can sequester 1,283,406 tonne CO_2 per year.

3.15 Emission Factors

The aboveground carbon stock was multiplied with 3.66 to develop emission factors for different forest strata of Gilgit-Baltistan (Table 20). Thus, local emission factors were developed which can be used to estimate emissions and removals in forestry sector of the region.

Table 20. Emission Factors for different forest strata

Forest Strata	**AGC (t/ha)**	**Emission Factors (CO_2 t/ha)**
Dense Broadleaved	60.78	222.45
Dense Conifer	91.65	335.44
Dense Mix	68.97	252.4302
Sparse Broadleaved	18.74	68.59
Sparse Conifer	20	73.2
Sparse Mix	25.77	94.32
Average	**47.65167**	**174.405**

4. RECOMMENDATIONS

The current study was the first-ever attempt to quantify carbon stock in the forests of Gilgit-Baltistan. As the journey towards REDD+ implementation in Gilgit Baltistan has just started and it will go a long way, there is need to explore new avenues of carbon accounting. In this context, the following points need consideration.

- As the current inventory covered only the aboveground biomass, there is a need to include other carbon pools in the future inventories.
- Large sample errors were reported for strata other than dense conifers, therefore, there is a need to collect additional data through laying out sample plots in these strata.
- Soil organic carbon is a significant pool of forest carbon but no data is available to quantify changes in soil carbon associated with deforestation and forest degradation.
- As REDD+ needs data on changes in carbon stocks associated with changes between different landuses, there is a need to conduct similar inventories in other landuses such as cropland, grassland, wetlands, settlements and other land uses to have local emission factors for GHG inventories.
- Remote sensing and GIS have crucial role in REDD+. There is a need to develop human and institutional capacity to undertake satellite based land monitoring system for performance based REDD+ in Gilgit Baltistan.
- The current inventory provided baseline of carbon stock in the forests of Gilgit Baltistan for 2016. It is essential to repeat this inventory after 3-5 years to quantify changes in the carbon stock over time.
- As carbon inventory is a cost and time consuming operation, it is therefore, recommended to train members of the communities to undertake carbon measurements in their forests in future.
- As the current inventory was confined to carbon estimation, it may be useful to assess other environmental variables, e.g. wildlife, birds, fungi, medicinal plants and other flora and fauna if the ultimate goal of the REDD+ is to incorporate biodiversity perspectives.

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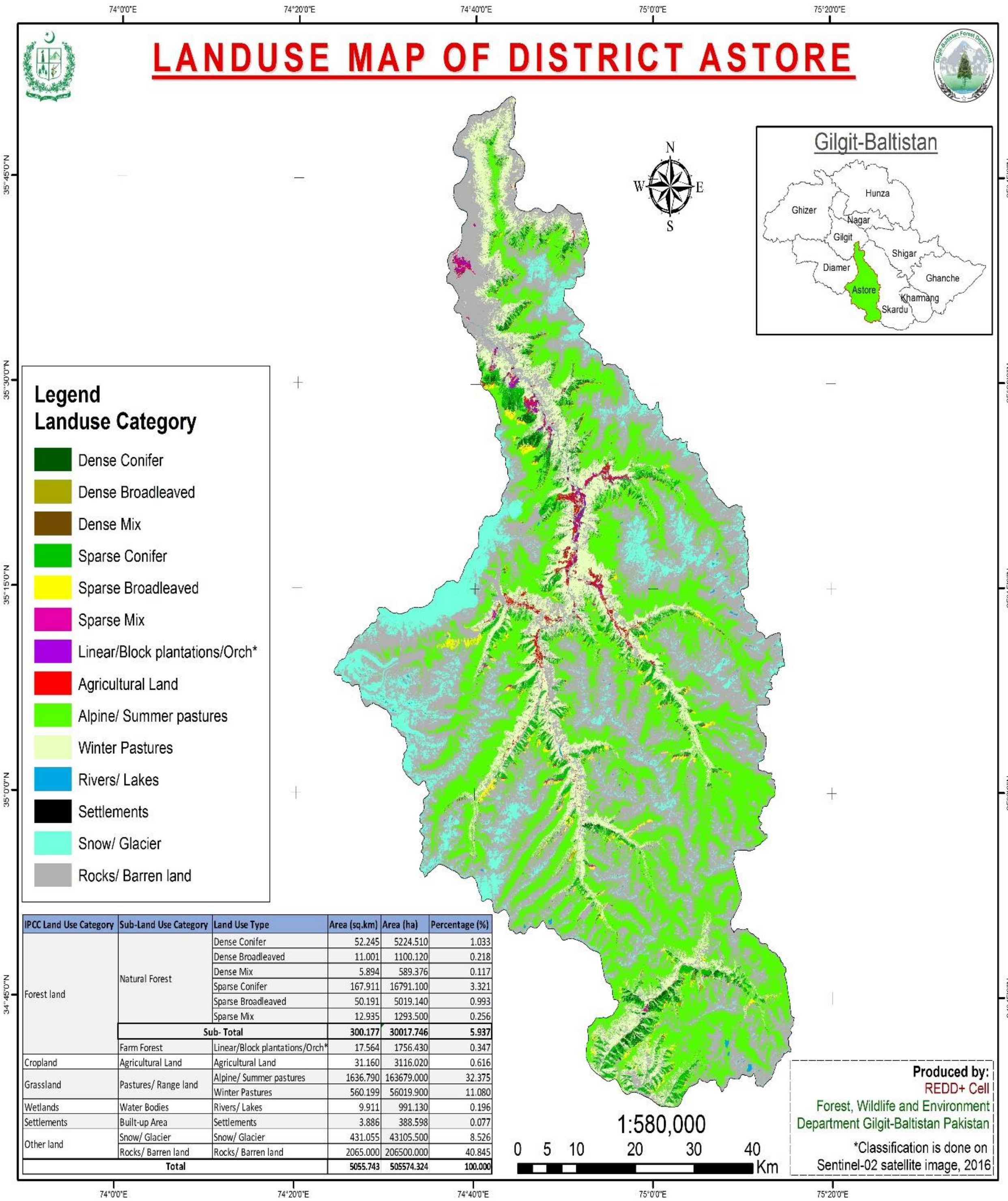
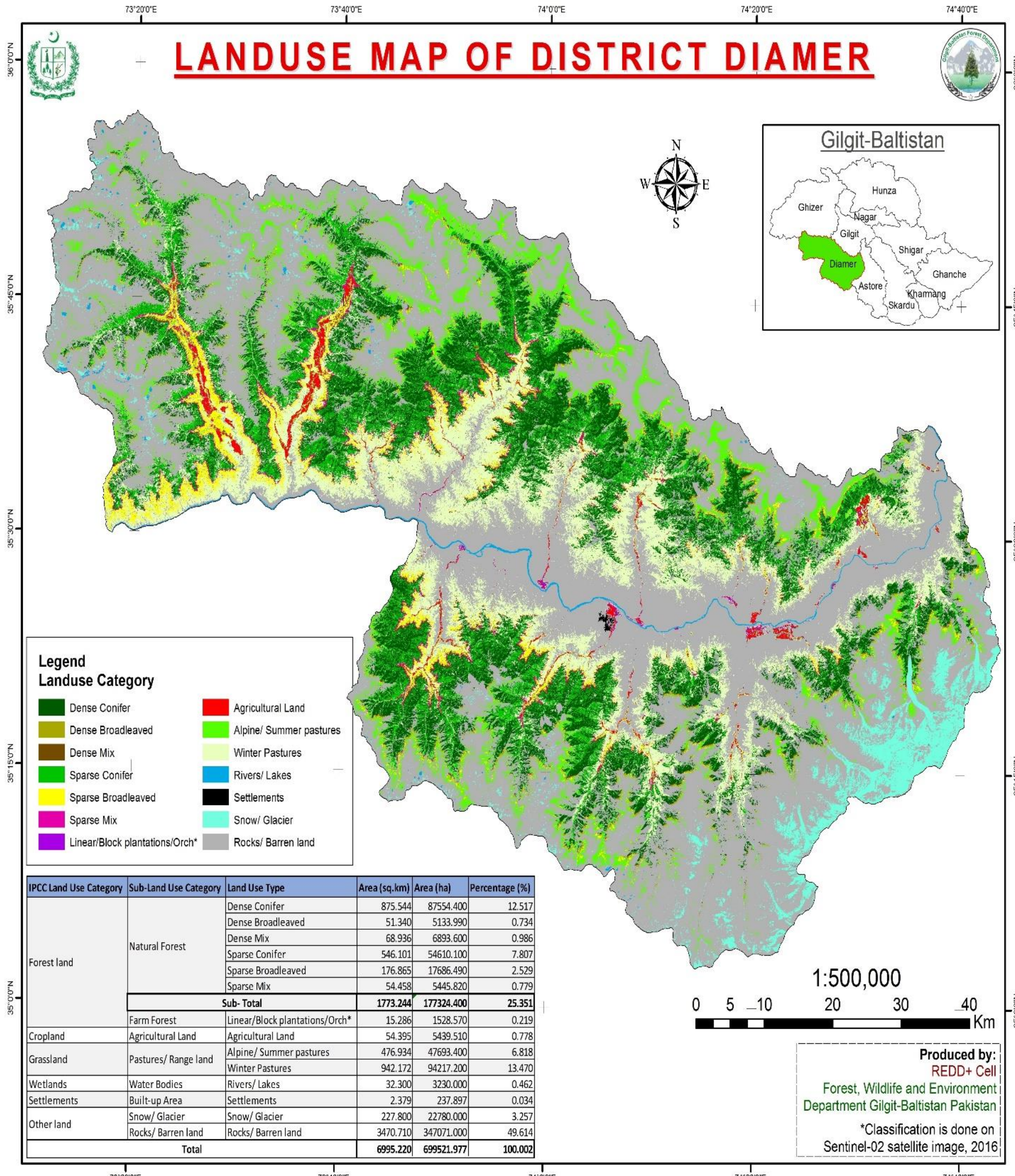
ANNEXURE I

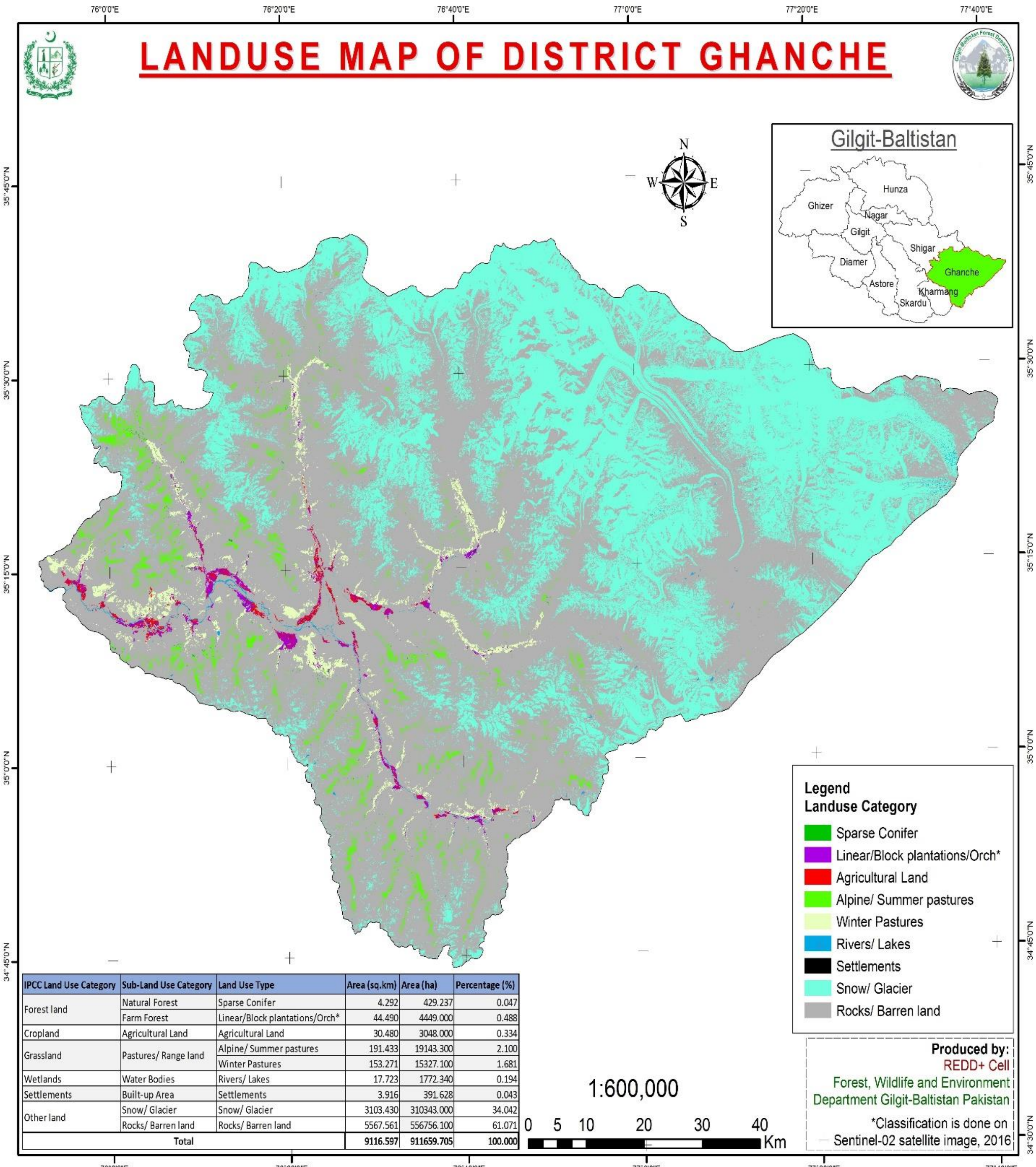
DISTRICT WISE LANUSE MAPS



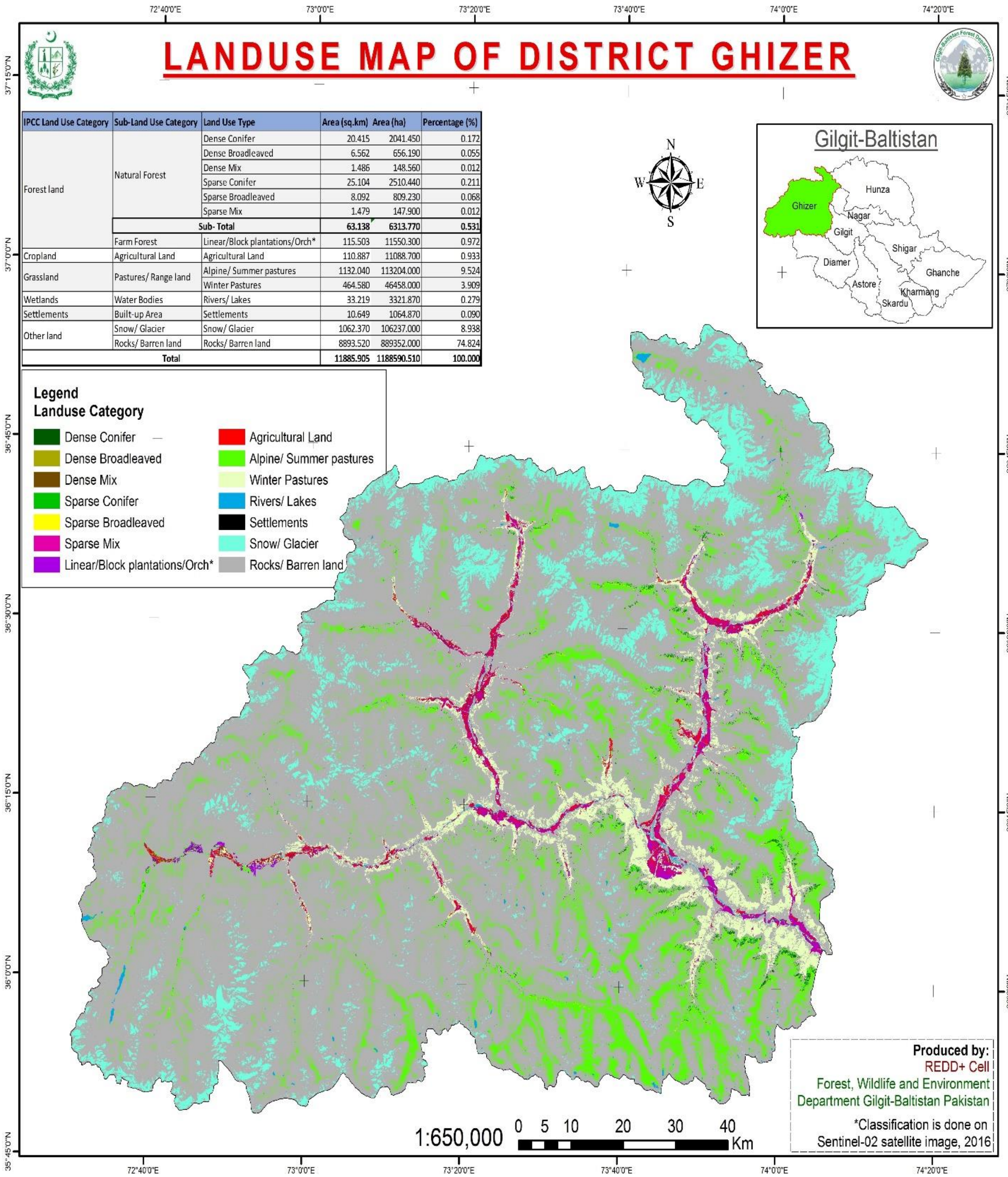
IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	Percentage (%)
Forest land	Natural Forest	Dense Conifer	52.245	5224.510	1.033
		Dense Broadleaved	11.001	1100.120	0.218
		Dense Mix	5.894	589.376	0.117
		Sparse Conifer	167.911	16791.100	3.321
		Sparse Broadleaved	50.191	5019.140	0.993
		Sparse Mix	12.935	1293.500	0.256
	Sub- Total		**300.177**	**30017.746**	**5.937**
	Farm Forest	Linear/Block plantations/Orch*	17.564	1756.430	0.347
Cropland	Agricultural Land	Agricultural Land	31.160	3116.020	0.616
Grassland	Pastures/ Range land	Alpine/ Summer pastures	1636.790	163679.000	32.375
		Winter Pastures	560.199	56019.900	11.080
Wetlands	Water Bodies	Rivers/ Lakes	9.911	991.130	0.196
Settlements	Built-up Area	Settlements	3.886	388.598	0.077
Other land	Snow/ Glacier	Snow/ Glacier	431.055	43105.500	8.526
	Rocks/ Barren land	Rocks/ Barren land	2065.000	206500.000	40.845
Total			**5055.743**	**505574.324**	**100.000**



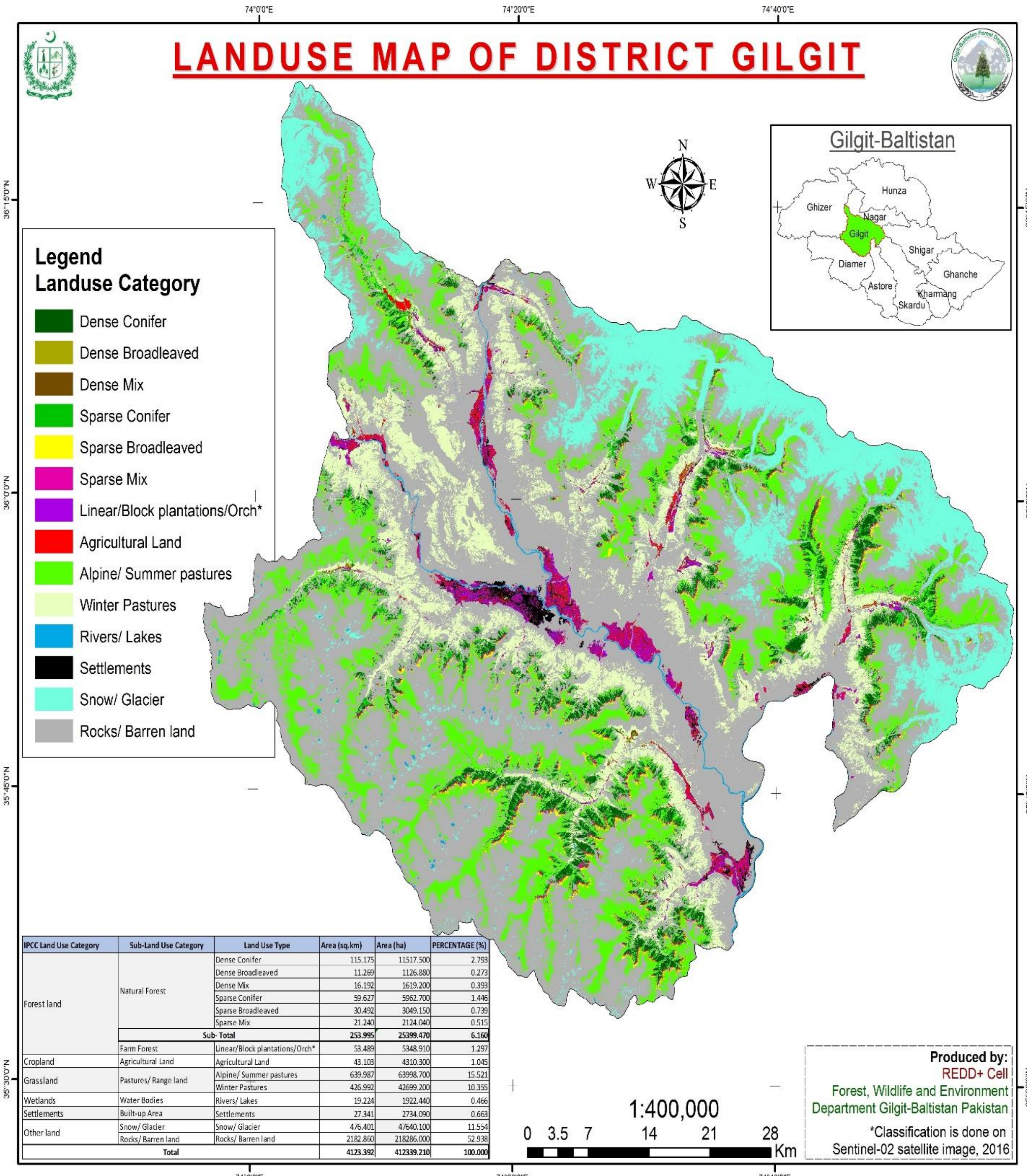
IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	Percentage (%)
Forest land	Natural Forest	Dense Conifer	875.544	87554.400	12.517
		Dense Broadleaved	51.340	5133.990	0.734
		Dense Mix	68.936	6893.600	0.986
		Sparse Conifer	546.101	54610.100	7.807
		Sparse Broadleaved	176.865	17686.490	2.529
		Sparse Mix	54.458	5445.820	0.779
	Sub- Total		**1773.244**	**177324.400**	**25.351**
	Farm Forest	Linear/Block plantations/Orch*	15.286	1528.570	0.219
Cropland	Agricultural Land	Agricultural Land	54.395	5439.510	0.778
Grassland	Pastures/ Range land	Alpine/ Summer pastures	476.934	47693.400	6.818
		Winter Pastures	942.172	94217.200	13.470
Wetlands	Water Bodies	Rivers/ Lakes	32.300	3230.000	0.462
Settlements	Built-up Area	Settlements	2.379	237.897	0.034
Other land	Snow/ Glacier	Snow/ Glacier	227.800	22780.000	3.257
	Rocks/ Barren land	Rocks/ Barren land	3470.710	347071.000	49.614
Total			**6995.220**	**699521.977**	**100.002**



IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	Percentage (%)
Forest land	Natural Forest	Sparse Conifer	4.292	429.237	0.047
	Farm Forest	Linear/Block plantations/Orch*	44.490	4449.000	0.488
Cropland	Agricultural Land	Agricultural Land	30.480	3048.000	0.334
Grassland	Pastures/ Range land	Alpine/ Summer pastures	191.433	19143.300	2.100
		Winter Pastures	153.271	15327.100	1.681
Wetlands	Water Bodies	Rivers/ Lakes	17.723	1772.340	0.194
Settlements	Built-up Area	Settlements	3.916	391.628	0.043
Other land	Snow/ Glacier	Snow/ Glacier	3103.430	310343.000	34.042
	Rocks/ Barren land	Rocks/ Barren land	5567.561	556756.100	61.071
Total			**9116.597**	**911659.705**	**100.000**

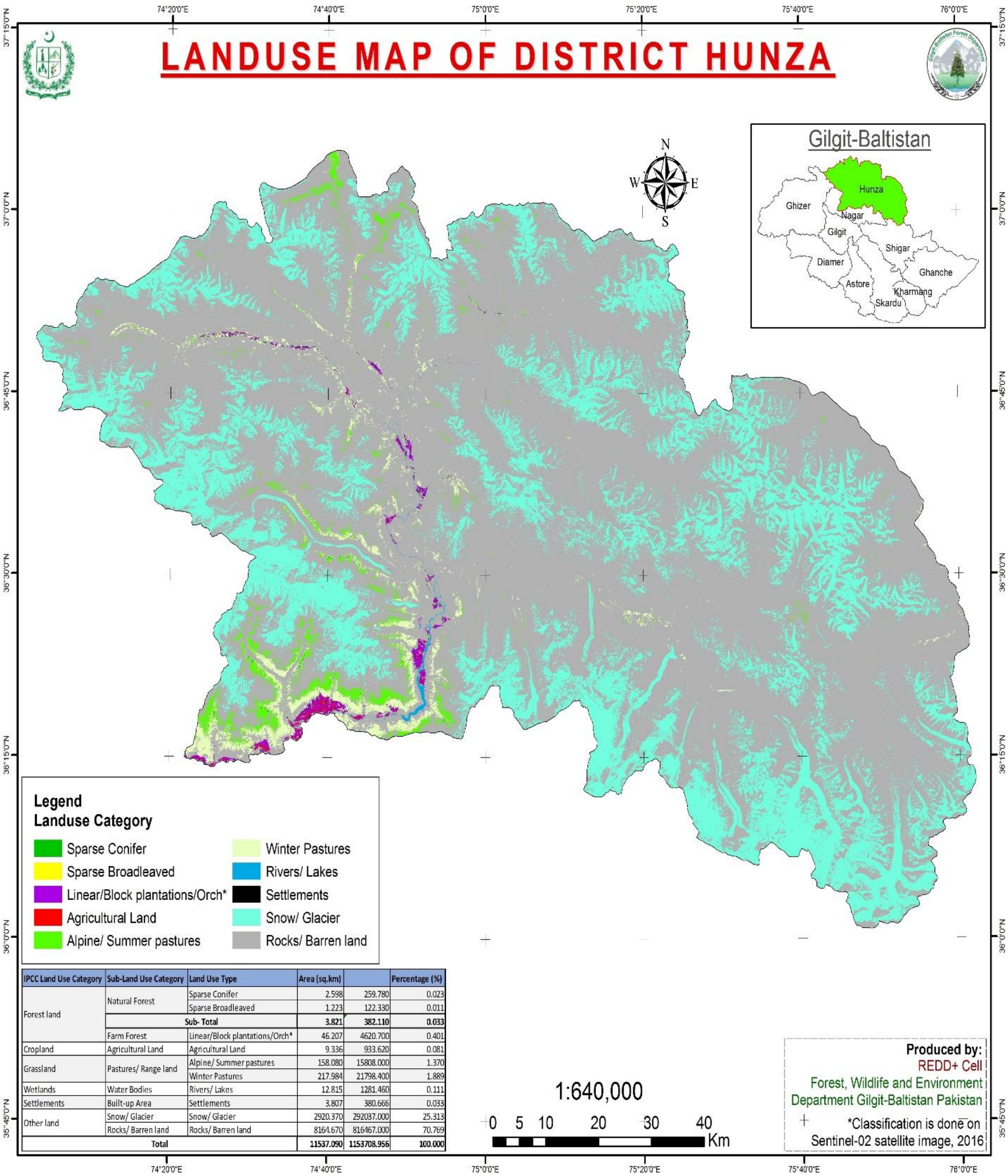


IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	Percentage (%)
Forest land	Natural Forest	Dense Conifer	20.415	2041.450	0.172
		Dense Broadleaved	6.562	656.190	0.055
		Dense Mix	1.486	148.560	0.012
		Sparse Conifer	25.104	2510.440	0.211
		Sparse Broadleaved	8.092	809.230	0.068
		Sparse Mix	1.479	147.900	0.012
	Sub- Total		**63.138**	**6313.770**	**0.531**
	Farm Forest	Linear/Block plantations/Orch*	115.503	11550.300	0.972
Cropland	Agricultural Land	Agricultural Land	110.887	11088.700	0.933
Grassland	Pastures/ Range land	Alpine/ Summer pastures	1132.040	113204.000	9.524
		Winter Pastures	464.580	46458.000	3.909
Wetlands	Water Bodies	Rivers/ Lakes	33.219	3321.870	0.279
Settlements	Built-up Area	Settlements	10.649	1064.870	0.090
Other land	Snow/ Glacier	Snow/ Glacier	1062.370	106237.000	8.938
	Rocks/ Barren land	Rocks/ Barren land	8893.520	889352.000	74.824
Total			**11885.905**	**1188590.510**	**100.000**

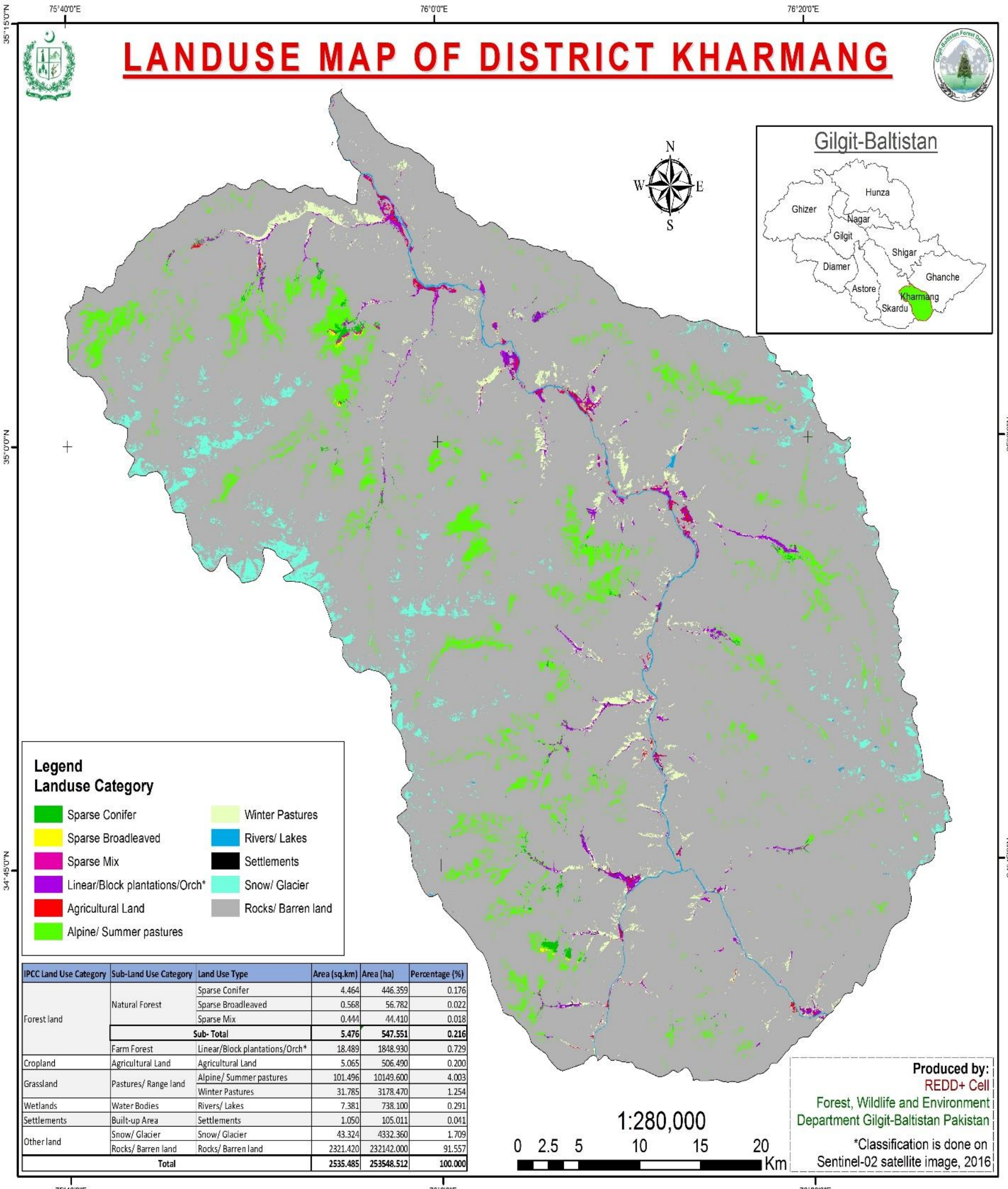


IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	PERCENTAGE (%)
Forest land	Natural Forest	Dense Conifer	115.175	11517.500	2.793
		Dense Broadleaved	11.269	1126.880	0.273
		Dense Mix	16.192	1619.200	0.393
		Sparse Conifer	59.627	5962.700	1.446
		Sparse Broadleaved	30.492	3049.150	0.739
		Sparse Mix	21.240	2124.040	0.515
	Sub- Total		**253.995**	**25399.470**	**6.160**
	Farm Forest	Linear/Block plantations/Orch*	53.489	5348.910	1.297
Cropland	Agricultural Land	Agricultural Land	43.103	4310.300	1.045
Grassland	Pastures/ Range land	Alpine/ Summer pastures	639.987	63998.700	15.521
		Winter Pastures	426.992	42699.200	10.355
Wetlands	Water Bodies	Rivers/ Lakes	19.224	1922.440	0.466
Settlements	Built-up Area	Settlements	27.341	2734.090	0.663
Other land	Snow/ Glacier	Snow/ Glacier	476.401	47640.100	11.554
	Rocks/ Barren land	Rocks/ Barren land	2182.860	218286.000	52.938
Total			**4123.392**	**412339.210**	**100.000**

LANDUSE MAP OF DISTRICT HUNZA

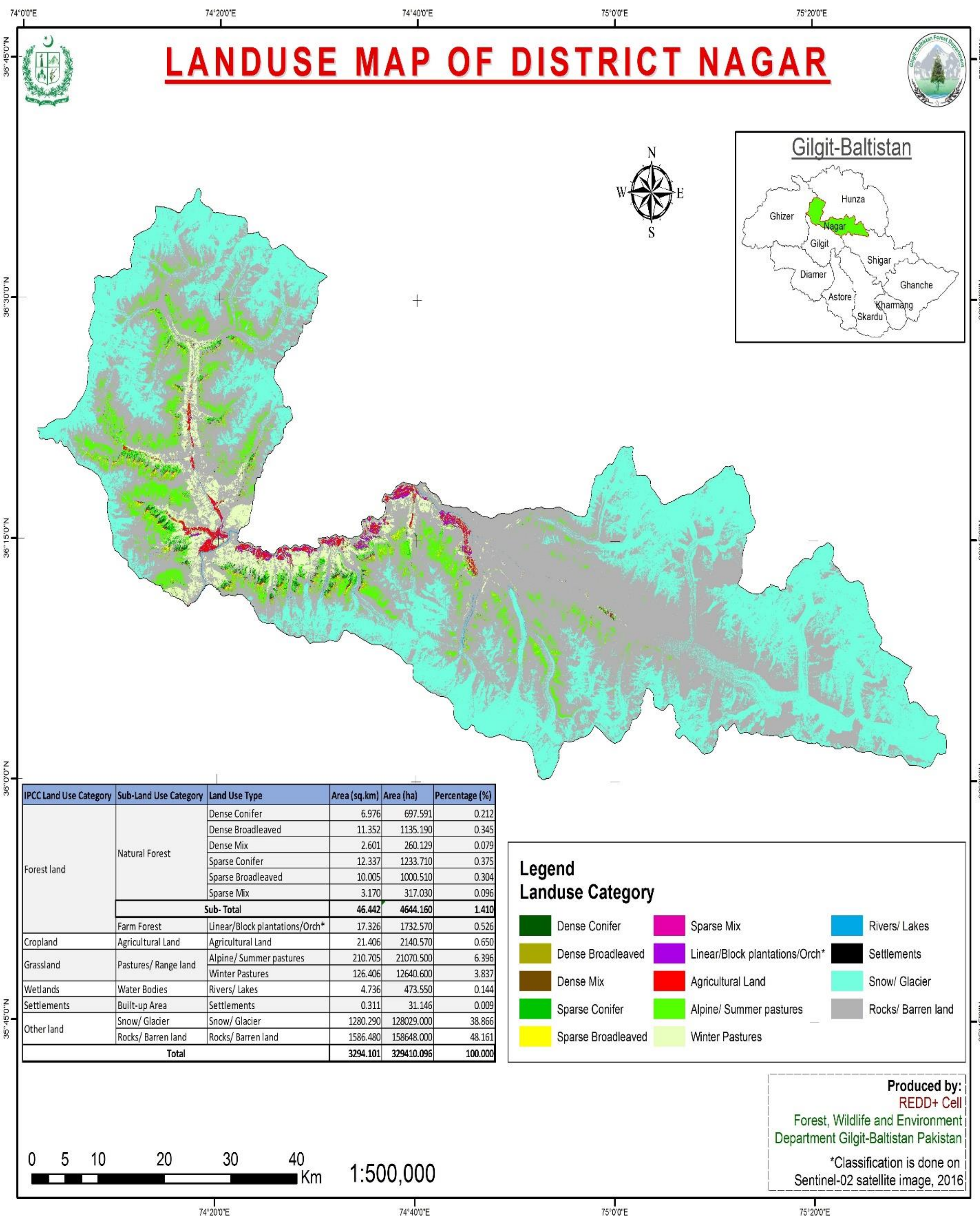


IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)		Percentage (%)
Forest land	Natural Forest	Sparse Conifer	2.598	259.780	0.023
		Sparse Broadleaved	1.223	122.330	0.011
	Sub- Total		**3.821**	**382.110**	**0.033**
	Farm Forest	Linear/Block plantations/Orch*	46.207	4620.700	0.401
Cropland	Agricultural Land	Agricultural Land	9.336	933.620	0.081
Grassland	Pastures/ Range land	Alpine/ Summer pastures	158.080	15808.000	1.370
		Winter Pastures	217.984	21798.400	1.889
Wetlands	Water Bodies	Rivers/ Lakes	12.815	1281.460	0.111
Settlements	Built-up Area	Settlements	3.807	380.666	0.033
Other land	Snow/ Glacier	Snow/ Glacier	2920.370	292037.000	25.313
	Rocks/ Barren land	Rocks/ Barren land	8164.670	816467.000	70.769
Total			**11537.090**	**1153708.956**	**100.000**



IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	Percentage (%)
Forest land	Natural Forest	Sparse Conifer	4.464	446.359	0.176
		Sparse Broadleaved	0.568	56.782	0.022
		Sparse Mix	0.444	44.410	0.018
	Sub- Total		**5.476**	**547.551**	**0.216**
	Farm Forest	Linear/Block plantations/Orch*	18.489	1848.930	0.729
Cropland	Agricultural Land	Agricultural Land	5.065	506.490	0.200
Grassland	Pastures/ Range land	Alpine/ Summer pastures	101.496	10149.600	4.003
		Winter Pastures	31.785	3178.470	1.254
Wetlands	Water Bodies	Rivers/ Lakes	7.381	738.100	0.291
Settlements	Built-up Area	Settlements	1.050	105.011	0.041
Other land	Snow/ Glacier	Snow/ Glacier	43.324	4332.360	1.709
	Rocks/ Barren land	Rocks/ Barren land	2321.420	232142.000	91.557
Total			**2535.485**	**253548.512**	**100.000**

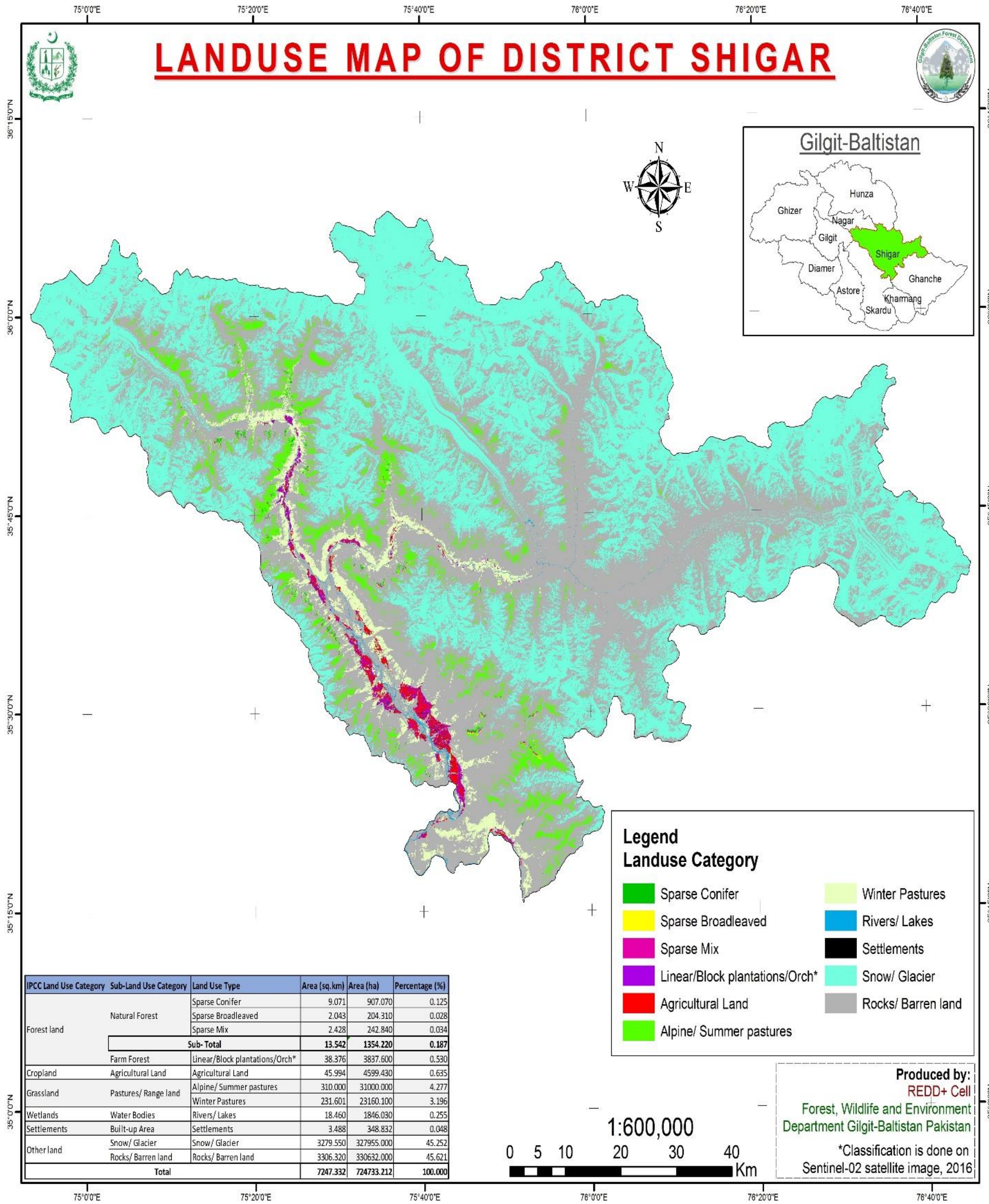
LANDUSE MAP OF DISTRICT NAGAR



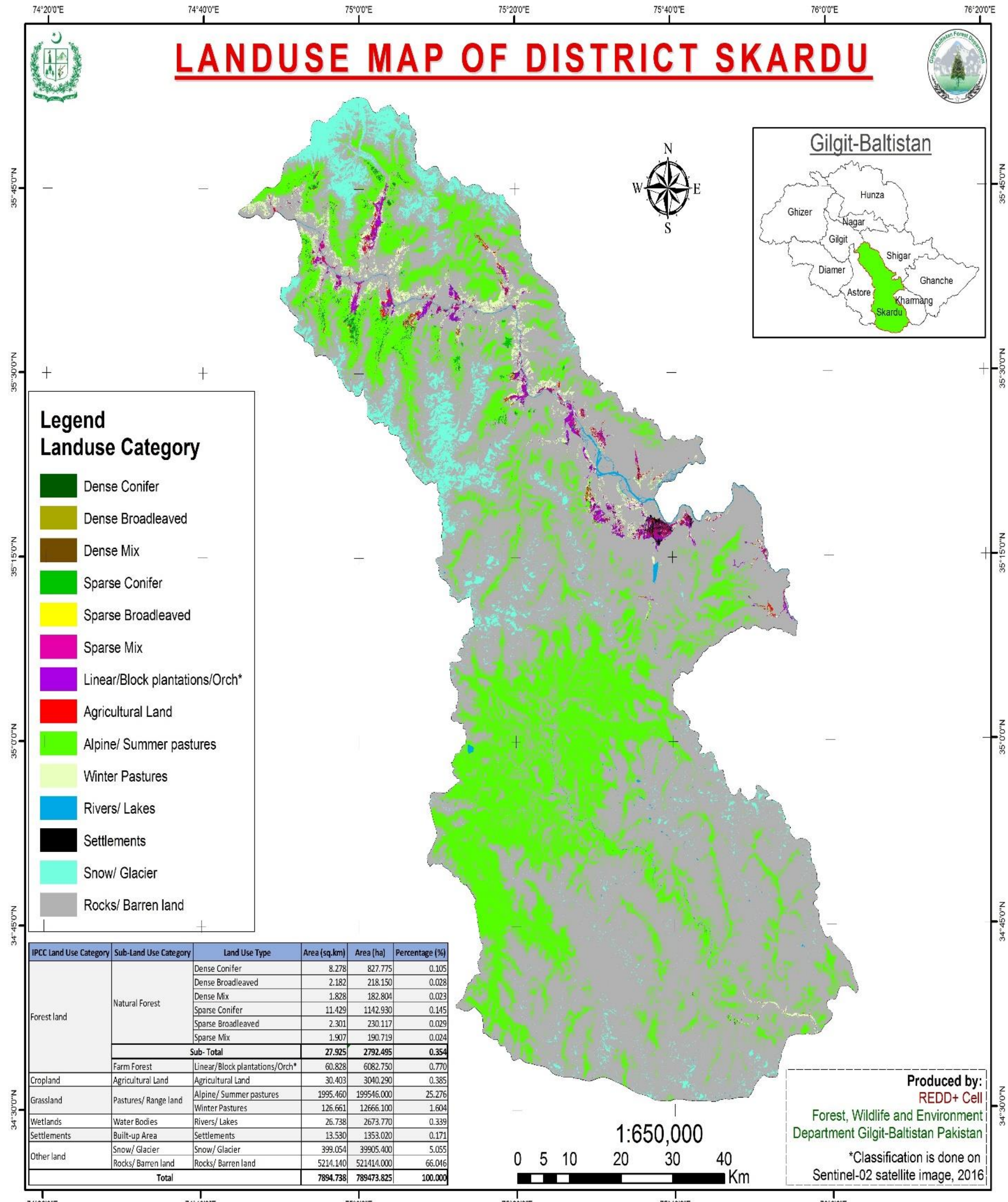
IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	Percentage (%)
Forest land	Natural Forest	Dense Conifer	6.976	697.591	0.212
		Dense Broadleaved	11.352	1135.190	0.345
		Dense Mix	2.601	260.129	0.079
		Sparse Conifer	12.337	1233.710	0.375
		Sparse Broadleaved	10.005	1000.510	0.304
		Sparse Mix	3.170	317.030	0.096
	Sub- Total		**46.442**	**4644.160**	**1.410**
	Farm Forest	Linear/Block plantations/Orch*	17.326	1732.570	0.526
Cropland	Agricultural Land	Agricultural Land	21.406	2140.570	0.650
Grassland	Pastures/ Range land	Alpine/ Summer pastures	210.705	21070.500	6.396
		Winter Pastures	126.406	12640.600	3.837
Wetlands	Water Bodies	Rivers/ Lakes	4.736	473.550	0.144
Settlements	Built-up Area	Settlements	0.311	31.146	0.009
Other land	Snow/ Glacier	Snow/ Glacier	1280.290	128029.000	38.866
	Rocks/ Barren land	Rocks/ Barren land	1586.480	158648.000	48.161
Total			**3294.101**	**329410.096**	**100.000**

Produced by:
REDD+ Cell
Forest, Wildlife and Environment Department Gilgit-Baltistan Pakistan

*Classification is done on Sentinel-02 satellite image, 2016



IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	Percentage (%)
Forest land	Natural Forest	Sparse Conifer	9.071	907.070	0.125
		Sparse Broadleaved	2.043	204.310	0.028
		Sparse Mix	2.428	242.840	0.034
	Sub- Total		**13.542**	**1354.220**	**0.187**
	Farm Forest	Linear/Block plantations/Orch*	38.376	3837.600	0.530
Cropland	Agricultural Land	Agricultural Land	45.994	4599.430	0.635
Grassland	Pastures/ Range land	Alpine/ Summer pastures	310.000	31000.000	4.277
		Winter Pastures	231.601	23160.100	3.196
Wetlands	Water Bodies	Rivers/ Lakes	18.460	1846.030	0.255
Settlements	Built-up Area	Settlements	3.488	348.832	0.048
Other land	Snow/ Glacier	Snow/ Glacier	3279.550	327955.000	45.252
	Rocks/ Barren land	Rocks/ Barren land	3306.320	330632.000	45.621
Total			**7247.332**	**724733.212**	**100.000**



IPCC Land Use Category	Sub-Land Use Category	Land Use Type	Area (sq.km)	Area (ha)	Percentage (%)
Forest land	Natural Forest	Dense Conifer	8.278	827.775	0.105
		Dense Broadleaved	2.182	218.150	0.028
		Dense Mix	1.828	182.804	0.023
		Sparse Conifer	11.429	1142.930	0.145
		Sparse Broadleaved	2.301	230.117	0.029
		Sparse Mix	1.907	190.719	0.024
	Sub- Total		**27.925**	**2792.495**	**0.354**
	Farm Forest	Linear/Block plantations/Orch*	60.828	6082.750	0.770
Cropland	Agricultural Land	Agricultural Land	30.403	3040.290	0.385
Grassland	Pastures/ Range land	Alpine/ Summer pastures	1995.460	199546.000	25.276
		Winter Pastures	126.661	12666.100	1.604
Wetlands	Water Bodies	Rivers/ Lakes	26.738	2673.770	0.339
Settlements	Built-up Area	Settlements	13.530	1353.020	0.171
Other land	Snow/ Glacier	Snow/ Glacier	399.054	39905.400	5.055
	Rocks/ Barren land	Rocks/ Barren land	5214.140	521414.000	66.046
Total			**7894.738**	**789473.825**	**100.000**

DATA COLLECTION FORM FOR REDD+ (GILGIT-BALTISTAN)

DISTRICT	Forest Range		Valley Name		Date
Name of Recorder	**Sampling Plot No.**	**Map Scale**	**Map No.**	**Dist. to Centre of Plot. (m)**	**Plot Radius Size (m)**

Geo Information of Sample Plot:

Latitude	Longitude	Bearing to Centre of Pl	Elevation (m)	Slope %	Aspect

Forest characteristics in Sample Plot:

Land Cover	Forest Use Type	Stand Composition	Type of Stand	Crown Cover (%)	Undergrowth

Sample Plot Data:

Tree No.	Tree Specie	DBH (cm)	Height (m)	Crown Dia.(m)	Tree Class
1					
2					
3					