Ministry of Climate Change

REDD+ Pakistan

Submission by Islamic Republic of Pakistan

FOREST REFERENCE EMISSION LEVELS

In the Context of Decision 1/CP.16 para 70 UNFCCC

Forest Reference Emission Levels

2019

Executive in charge

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Acknowledgements

(To be added in final version)

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ABBREVIATIONS

AD	Activity Data
AFOLU	Agriculture, Forestry and Land Use
AGB	Aboveground Biomass
AGC	Aboveground Carbon
AJK	Azad Jammu & Kashmir (autonomous territory)
ASAD	Applied System Analysis Division
BAU	Business as Usual
BEF	Biomass Expansion Factor
BGB	Belowground Biomass
BGC	Belowground Carbon
BN	Balochistan (province)
cm	Centimetre
CO2-e	Carbon Dioxide Equivalent
CoP	Conference of Parties
CPEC	China Pakistan Economic Corridor
DBH	Diameter at breast height (at 1.3 m or 1.37 m height from the ground level)
DOS	Dark Object Subtraction
DWC	Deadwood Carbon
EF	Emission Factor
FAO	Food and Agriculture Organization of the United Nations
FATA	Federally Administered Tribal Areas
FCPF	Forest Carbon Partnership Facility
FD	Forest Department (provincial)
FOSS	Free and Open-source Software

EXECUTIVE SUMMARY

The total land area of Pakistan as published by the Survey of Pakistan (SOP) is 796,096 km^2 including Islamabad Capital Territory (ICT), Balochistan (BN), Khyber Pakhtunkhwa (KP), Punjab (PB), Sindh (SD) and Federally Administered Tribal Areas (FATA). After including the territories of Gilgit-Baltistan (GB) and Azad Jammu & Kashmir (AJK) the total REDD+ programme area is defined as 879,106 km^2.

Status of Forest Cover at the National Level

The total forest cover assessed by the consultant in 2012 is **5.4 %** of the total land area assessed. The national forest cover has been assessed for **5** reference years[1] including 1996, 2000, 2004, 2008 and 2012 based on **notified national forest definition**. This does not include the fruit trees in orchards and farmland trees.The mean national forest cover estimates vary from 5.4 to 5.6 percent between the years with uncertainty of ± 0.8% between 2004 and 2012.

Years	Forest Area (Ha)	% Area
2004	4981118	5.67%
2008	4854949	5.52%
2012	4786346	5.44%

Table 1: Historical Assessment of Forest Cover at National Scale

By forest type, dry temperate forests have the largest proportional coverage (36 %) followed by scrub (19 %), moist temperate (15 %), pine (13 %), riverine (2%), irrigated plantation (5 %), sub-alpine (2 %), thorn (4 %) and mangrove forests (2 %). The mean forest carbon stock is about 191 Million tons in 2004-2012.

Assessment of Deforestation

Due to limited reference data availability, the deforestation has been assessed from 2004-2012 period. The average annual deforestation has been estimated up to about 12,000 hectares, whereas, an increasing trend of more than 18000 ha was observed from 2008-2012.

Deforestation has had the highest average annual rates scrub (25 %), thorn (14 %), pine (17 %), irrigated plantations (18 %) and dry temperate forests (13 %).

[1] As reference data availability is very limited for the reference years before 2004, this leads to some increased uncertainty (accuracy and precision) in terms of forest cover estimates for the individual years before that date. The average precision of the national forest cover error-adjusted estimates for 2004, 2008 and 2012 was quantified as about ±15 percent with 95-% confidence level.

National Forest Emissions Level (FREL)

The mean annual emissions from the deforestation are 1.0 Million tons of CO_2-e between 2004 and 2012 with the increasing emission trend from deforestation. The largest share of CO2 emissions originates from moist temperate (25 %), dry temperate (23 %) and pine forests (20 %) followed by followed by riverine (2 %), scrub (10 %) and thorn (4 %) forests in 2004-2012. Based on above, the FREL has been estimated as **1.0 Mt CO_2-e**.

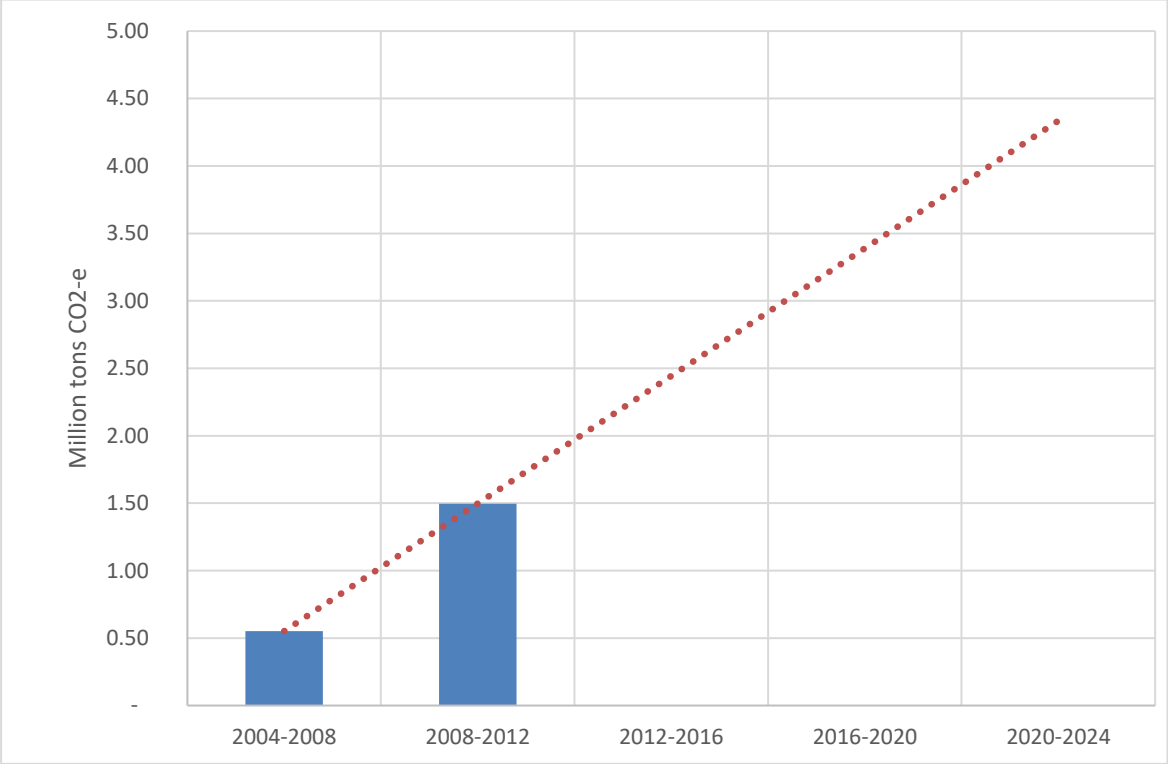


Figure 1 Mean annual emissions (Mt CO_2-e) from deforestation (2004-2012) and projection (2012-2022) at national level

PREFACE

Addressing drivers of deforestation and forest degradation has been at the heart of REDD+ discussions and UNFCCC negotiations since many years. Decision 2 of COP 13 in Bali already encouraged Parties “to explore a range of actions, identify options and undertake efforts, including demonstration activities, to address the drivers of deforestation”. Decision 1 of COP 16 reiterated the need for all parties to take actions to address drivers of deforestation (para 68) and requested developing countries, to address drivers of deforestation and forest degradation when developing and implementing their national strategies and action plans (para 72).

The dynamics and causes of deforestation and forest degradation are multi-faceted, complex and vary from place to place. Direct drivers are associated with a complex set of underlying drivers that need to be tackled if efforts to address the direct drivers are to be successful in the long-term.

Pakistan has prepared the first FREL in this submission which has been developed with the financial support of the Forest Carbon Partnership Facility under Readiness Fund. This submission is based on UNFCCC requirements by following the guidance for technical assessment and adopting principals on transparency, accuracy, completeness and consistency.

The Ministry of Climate Change through its National REDD+ Office led the process for establishment of FREL with support of an international consulting firm Arbonaut Oy. in Joint Venture with WWF-Pakistan by engaging the relevant REDD+ Stakeholders including Provincial Forest Departments, REDD+ Working Groups, and Provincial REDD+ Focal Points etc.

The scope of this FREL covers deforestation activity in natural forests assessed based on nationally adopted standards covering the aboveground and below ground Carbon Pools.

1. INTRODUCTION

Climate change is the single most important threat to humanity and ecosystems The forestry sector, commonly considered as bearing a high natural capital value for the society and also a safeguard against climatic threats, has suffered heavily during the past two decades. The current forest cover of Pakistan is extremely inadequate when considering exposure of the country to future climatic threats. A number of factors have contributed to deforestation: prominent among these being poverty, population pressures and lack of fiscal space for strong policy initiatives in protecting forests. Even though Pakistan is a small emitter of global GHG emissions, it is included in the top ten countries in the world most vulnerable to the impacts of climate change, (Global Climate Risk Index developed by German Watch 2019).

The current population of 207.8 million (GoP, 2018) places the country at the sixth most populous country of the World. At an average economic growth rate of 4.9 percent from 1952 to 2015 (GoP, 2016) with increase to 5.4 percent on average from 2016 to 2018 (GoP, 2018), Pakistan is classified as lower middle-income and agrarian country primarily (GoP, 2016). The population directly and indirectly associated with the agriculture sector is estimated to be 42.3 percent (GoP, 2017) with a contribution of 18.9 percent to the overall GDP of the country. The forestry sector has the current share of 0.39 percent in overall national GDP posted a growth of 7.17 percent in 2018 (-2.37 percent in 2017) due to higher timber production reported by Khyber Pakhtunkhwa province (GoP, 2018).

Pakistan is mainly a dry land country with 80 percent of its land in arid and semi-arid areas. According to the forest definition the total forest land has been assessed as about 4.77 million hectares, which is 5.4 percent of the country territory in 2012.The officially reported area subject to afforestation is about 123,500 hectares between 2009-2013**.** Besides there are also about 57,912 km of linear plantations reported under control of the Provincial and State Forest Departments.

The official country territory is as reported and published by the Survey of Pakistan (SOP) is 796,096 km2 including Islamabad Capital Territory (ICT), Balochistan (BN), Punjab (PB), Sindh (SD) and Federally Administered Tribal Areas (FATA) which has been lately merged administratively with Khyber Pakhtunkhwa (KP). Gilgit-Baltistan (GB) and Azad Jammu and Kashmir (AJK) are referred as “Disputed Territory” without demarcating the international border (SoP, 2012). Therefore, the land areas of these two provinces are not officially published.

1.1 Relevance

The country is highly exposed to the future climatic threats. The forestry sector, commonly considered as bearing a high natural capital value for the society and a safeguard against climatic threats, has suffered heavily during the past two decades (R-PP MTR, 2017).The increasing trend in projected emissions from forest sector has been attributed to the threat of accelerated deforestation and forest degradation in many parts of the country in the wake of rising population and associated wood demands, weak governance of tenure, encroachments and land cover changes superimposed by adverse impacts of climate change.

Several socio-economic factors have been reported to accelerate the deforestation trends in the country (GoP, 2016), such as prominent among these being poverty, population pressure and lack of fiscal space for strong policy initiatives in protecting forests. Considerable efforts are being taken by the GoP for the revival of forestry in the country. These efforts include expanding the forest cover through mega tree plantation programmes strengthening the regulatory and forest protection policy mechanism, and implementation of international mechanisms under the United Nations Framework Convention on Climate Change (UNFCCC), such as, reducing emissions from deforestation and forest degradation with conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+).

A solid foundation for REDD+ was laid by the MOCC in 2010 with the notification of the National Focal Point (NFP) for REDD+ followed by notification of provincial focal points in all provinces and territories of Pakistan. The REDD+ initiatives received the full governmental ownership with the inclusion of REDD+ in the Climate Change Policy 2012 (GoP, 2012).

In 2013 four working groups were formed on governance and management of REDD+; stakeholder engagement and safeguards; national forest monitoring system (NFMS); measurement, reporting and verification (MRV); and drivers of deforestation and forest degradation. The National Thematic Working Groups (WG) serve as national platforms that engage stakeholders in scientific discussions, plan and organize research, collect data and serve as platform for providing the National Steering Committee (NSC) on REDD+ with validated data and information for its decisions. Pakistan's National Forest Policy 2015 (GoP, 2015) approved by the Council of Common Interest under the chairmanship of the Prime Minister of Pakistan in November 2016 also gives provisions for mainstreaming REDD+ as a tool to curb deforestation and enhance forest cover and forest carbon stocks. The coordination functions of the National REDD+ Office are to be taken over by the Pakistan Climate Change Authority established under Section 5 of the Climate Change Act, 2017.

1.2 General Approach

The UNFCCC invites Parties to submit information and rationale on the development of their FREL and/or FRL, including details of the national circumstances, and if adjusted including details on how the national circumstances were considered in accordance with the guidelines contained in annex to decision 12/CP.17. Paragraph (b) of the annex to decision 12/CP.17 enquires parties to provide transparent, complete, consistent and accurate information, including methodological information used at the time of construction of FREL and/or FRL, including, inter alia, as appropriate, a description of data sets, approaches, methods, models and assumptions used, descriptions of relevant policies and plans, and descriptions of changes from previously submitted information. Further guidance was provided in Decision 13/CP.19 which require country parties to provide description of relevant policies and plans (Paragraphs d & e) to include assumptions about the future changes to domestic policies in construction of the FREL and/or FRL (Paragraph h).

FREL/FRLs are guided as benchmarks for assessing REDD+ performance by modalities contained in UNFCCC Conference of Parties (CoP) decisions, most notably decision 12/CP.17 and its Annex. These modalities state that when establishing FREL/FRLs, Parties should do that transparently considering historic data and adjust them for national circumstances. A stepwise approach is allowed that enables Parties to improve the FREL/FRLs by incorporating better data, improved methodologies and, where appropriate, additional carbon pools. A FREL/FRL must maintain consistency with a country's greenhouse gas inventory (according to 12/CP.17, Paragraph 8).

A summary of Pakistan's FREL compliance with these UNFCCC decision modalities is given in Table 1.

Table 1 Pakistan's FREL compliance concerning the relevant UNFCCC COP decisions

UNFCCC reference	Description	Pakistan's FREL
Decision 12/CP. 17 II. Paragraph 9	Submission of information and rationale on the development of forest FRL/FRELs, about the details of national circumstances and their consideration	- The methodological details included in the FREL technical document and its annexes.
Decision 12/CP.17 II Paragraph 10	Stepwise approach	- Developing FREL following a gain-loss approach for Tier 2 emission factors (EF) derived with sub-national datasets. - The first submission with available data and its subsequent analysis supporting selection of relevant activities and pools.
Decision 12/CP. 17 Annex II. Paragraph 9	The information contents guided by the most recent IPCC guidance and guidelines Submission of information and rationale on the development of forest FRL/FRELs, about the details of national circumstances and their consideration	- 2006 IPCC Guidelines have been adopted to guide the development besides the UNFCCC decisions. - The methodological details included in the proposed FREL technical document and in its annexes.
Decision 12/CP.17 Annex, paragraph I	Activities	- Inclusion of deforestation.
Decision 12/CP.17 Annex, paragraph (c)	Pools and gases	- CO_2 emissions from above-ground (AGB) and below-ground biomass (BGB) pools.
Decision 12/CP.17 Annex, paragraph (d)	Forest definition applied in the GHG inventories	- Forest definition notified in September 2017 - Tier 2 emission factors produced by the main forest types.

1.3 The Objectives of this Submission

The first objective is to present a national FREL figure for REDD+ implementation in Pakistan and to assess effectiveness of Policies and Measures (PAMs) through a clear, transparent, accurate, complete and consistent estimates of carbon emissions from forestry sector.

The second objective is to fullfill a global responsibility to report the national contribution to the mitigation of climate change

A final objective is to access results based REDD+ Finance for reducing emissions

1.4 Process of FREL establishment

In scope of the REDD+ readiness Pakistan has started proceeding stepwise by developing the first national FREL for the establishment of FREL with support of an international consulting firm Arbonaut Oy. in Joint Venture with WWF-Pakistan. The consultant worked in collaboration with Ministry and other REDD+ Stakeholders including Provincial Forest Departments, REDD+ Working Groups, and Provincial REDD+ Focal Points etc. The following stepwise process was adopted:

Step 1: Establishment of National Standards

1.4.1 Definition of Forest

The national definition of forest complies with the following definition:

“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.”

1.4.2 Deforestation

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).

1.4.3 Activity data

The data on the magnitude of human activities resulting in emissions or removals taking place during a given period of time (UNREDD 2013).

1.4.4 Emission factors

Emission factors for deforestation represent average net carbon dioxide (CO2) emissions per hectare of land when forest land has been converted to non-forest.

1.4.5 FREL / FRLs

FRELs and / or FRL are benchmarks for assessing Countries performance on REDD+. Though the UNFCCC does not explicitly specify the difference between a FREL and a FRL, the most common understanding is that a FREL includes only emissions from deforestation and degradation, where as a FRL includes both emissions by sources and removals by sinks, thus it includes also enhancement of forest carbon stocks.

FREL refers to average gross annual emissions as CO2-equivalent tons per year. This average is calculated using activity data and emission factors for each forest stratum separately with the following formula:

FREL (tons CO2 in average per year) = Annual deforestation (hectares in average per year) X EF (tons CO2-e of average emissions per hectare)

1.4.6 Forest Stratification

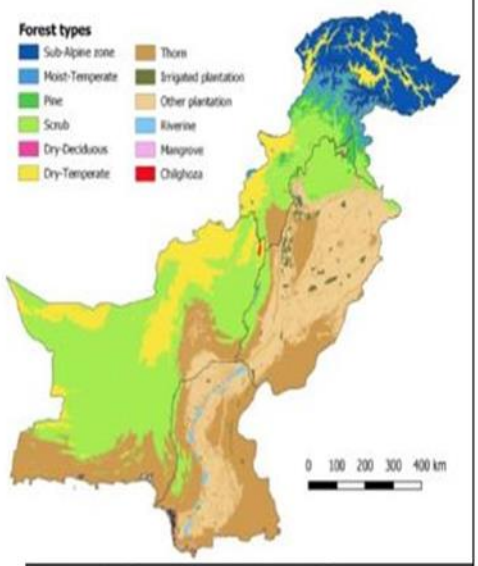
The forest stratification has been adapted from the classification scheme published and revised by Champion et al. (1965) (Figure 1). As part of the FREL development process a spatial information layer has been generated primarily with help of the global spatial data available for altitude, range, slope, orientation, weather data (average annual temperature/rainfall) and geographic distribution annotations by Champion et al. (1965) (Table 2).

Table 2 Forest strata, altitude range, mean rainfall and temperatures (adapted from Champion et al., 1965)

Forest Stratum	Altitude range (Northern/ Southern Aspect)	Mean annual rainfall	Mean minimum temperature[13]
Littoral and Swamp (Mangroves)	Max 3 m	16-23 cm	16 °C
Thorn	3-385 m	5-49 cm	10 °C
Dry deciduous	253-510 m	83-107 cm	10 °C
Scrub	457-1524 m	12-98 cm	7 °C
Pine	914-1676/2134 m	77-162 cm	13 °C
Moist temperate	1524-3048 m	64-152 cm	2 °C
Dry temperate	1524- 3353/3658 m	14-74 cm	-4 °C
Sub-Alpine	3353- 3810/3962 m	< 66 cm	-13 °C

Forest Stratification

Main Forest Stratum	Sub-Stratum
1.1 Littoral and swamp forest	1.1.1 Mangroves
1.2 Dry deciduous forest	
1.3 Thorn forest	
1.4 Riverine forest	
2.1 Broad- leaved evergreen forest	2.1.1 Montane sub-tropical scrub
	2.1.2 Sub-tropical broad-leaved
2.2 Pine forest	
3.1 Moist temperate forest	
3.2 Dry Temperate forests	3.2.1 Montane Dry Temperate Coniferous
	3.2.2 Dry temperate Juniper and Chilghoza
	3.2.3 Dry Temperate broad-leaved
	3.2.4 Northern Dry Scrub
4.1 Sub-Alpine Forests	
5.1 Linear Plantations	5.1.1 Roadside plantations
	5.1.2 Railway side plantations
	5.1.3 Canal side plantations
5.2 Irrigated Plantations	



Stratification by main Forest types

Figure 1: Forest Stratification

Step 2: Field and Satellite based inventories

Field and satellite based data was acquired and assessed for a period from 1992 to 2012. Land use, land cover classification and time-series analysis has been conducted using 55 historical Landsat satellite image scenes acquired for each reference year.

Forest inventory data for Khyber Pakhtunkhwa and Gilgit Baltistan was used as existing data, whereas, field data for Punjab, Sindh, Balochistan and AJK (Disputed Territory) was collected from two phased sampling approach. After careful assessments and consultation with stakeholders the data points of 2004 onwards were considered reliable due to lack of reference data before 2004.

2. FREL ESTABLISHMENT (AREA, ACTIVITIES AND POOLS COVERED)

2.1 Area Covered

The official country territory as reported and published by the Survey of Pakistan (SOP) is 796,096 km2. For the FREL development purposes the national and provincial boundaries have been digitized from the administrative boundary map originating from the SOP. Besides the national FREL covers the territories of GB (69,713 km2) and AJK (Disputed Territory) (13,297 km2) according to the area extent references provided by the respective sub-national units. The mangrove forest patches and estuaries with vegetation in the Southern coastal regions in BN and SD have been included. The total FREL area sums up to 879,106 km2 including the provinces and states as the sub-national units.

2.2 REDD+ Activities

Deforestation refers to the activity when forest land is directly converted to non-forest land due to anthropogenic means. Deforestation has been identified as the key activity category for developing FREL, therefore, considering the resources and time constraints first submission of Pakistan's FREL only contains deforestation at national scale.

The definition of **Forest degradation** was worked upon during the sixth Working Groups meeting of REDD+, however, further deliberations are required. The emission factors and Activity Data for forests land remaining as forests land activity category could not be accounted due to lack of reliable multi-temporal ground measurements at national level or even for surrogate data (proxy measures). Currently, a nationally representative coverage for forest growth, wood removal and disturbance data to produce reliable estimates for annual forest degradation rate are being prepared in additional funding activities of R-PP.

When non-forest land is converted to forest land, tree vegetation is restored through, either, afforestation, reforestation or natural regeneration sub-activities, and is considered as the third activity category. **Carbon stock enhancement** takes place through forest restoration (afforestation, reforestation and natural regeneration) and forest growth, but there is very limited growth research and modelling base for accounting emission removals through these activities.

The **Sustainable Forest Management** and **Conservation** of Forest Carbon Stock are included in scope of future FRL, but potential emissions are reported as part of the deforestation activity. Reporting sustainable forest management and conservation activities separately would require including them as additional strata for collecting carbon-stock inventory time-series data and

aggregating harvesting statistics at forest management and conservation unit level consistently throughout the country.

2.3 Carbon Pools and Gases

The Readiness Preparation Proposal (R-PP, 2013) declares that carbon pools included in the FREL/FRLs are to be limited initially to above-ground biomass. As more information becomes available, for instance from field assessments stored in the NFMS, other carbon pools may be incorporated, possibly stratified by forest type, as FREL/FRLs are periodically updated and as suggested in Decision 12/CP.17 paragraph 10.

The aboveground, belowground and soil carbon pools form 93-99 % of the total forest carbon stock in Pakistan according to the NFI pilot inventory data. There is an immediate change in above-ground and belowground carbon stocks after a forest is harvested, as a significant part of them are converted to timber and deadwood pools.

The Soil Organic Carbon (SOC) change dynamics is very much subject to land management applied and the gradual change is accounted over a period of 20 years in scope of the GHG-I accounting (IPCC, 2006). During the pilot NFI campaign it was found in some forest areas that the SOC contents was even higher outside the forestland depending on the applied land management. Monitoring and modelling soil carbon changes also requires implementing permanent soil monitoring design under different forest management regimes.

The terrestrial carbon pools included in the first FREL submission are aboveground and belowground biomass. The greenhouse gases accounted from the selected forest pools cover carbon dioxide (CO2) only.

In the context of national greenhouse gas inventories, it is mandatory for Non-Annex countries to report the CO_2, CH_4 and N_2O emissions. Carbon dioxide must be always 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 forest, but those activities are taking place rarely in Pakistan. There are no certain prospects that these activities would get more widely promoted in the forestry sector. If their importance increases as emission sources, they can be included following a stepwise approach in the future FREL/FRL submissions.

3. DATA, METHODOLOGY AND PROCEDURE

Pakistan follows a development approach based on the historical average of emissions from deforestation. Activity data is accounted for periods of 2004-2008 and 2008-2012. The two periods for temporal change assessments are considered as a reliable basis to create a projection for predicting the future business as usual trends. The past trends in gross deforestation is assessed through activity data mapping. Modelling historic emissions relies on the activity data produced with the documented Satellite Land Monitoring System (SLMS) methodology and time-series analysis.

For the Forest Stratification (as referred in section 2.6) the spatial reference layer has been complemented with land cover / use classification and map reference data received from the provincial FDs regarding irrigated plantations and riverine forests. The existing statistics have been referred for the total irrigated plantation, riverine forest land cover and linear plantations, wherever the specific forest cover class was difficult to assess. The mangrove forest land area reference extent is sourced from the remote sensing study published by Abbas et al. (2013).

The recent pilot NFI plot data (2017/2018) has been used to validate the resulting spatial information layer by comparing the classified forest areas to indicator tree species information. The geographical distribution limits, structural characteristics and indicator species composition are summarised for each forest type in the following paragraphs using Champion et al. (1965) as the principal reference source.

The nationally harmonised emission factors have been developed with a reference to the previous forest carbon stock inventories. The pilot national forest inventory (NFI) measurements have been conducted in October 2017–April 2018 covering all the main forest types in AJK (Disputed Territory), PB, SD, BN and FATA. There has been also conducted a provincial forest carbon inventory campaign in 2013-2016 providing aboveground and belowground carbon data coverage in KP (Ali, 2017). The other provincial carbon inventory has been also completed in Gilgit-Baltistan including above-ground and belowground carbon pools in 2015-2016 (Ali et al., 2017). The total carbon densities for different forest strata and other land uses are used to derive emission factors (EF)[2].

All the emission calculations are conducted by the main forest types and then aggregated as national level estimates. It is assumed that sustainable forest management is implemented in the government owned irrigated plantations, so that there are no permanent deforestation events inside their boundaries, and they are carbon neutral in terms of emissions.

3.1 Data Collection

3.1.1 Mapping for Activity Data for Deforestation

Activity data mapping is based on the LULC classification using Landsat imagery (5/7/8) for each of the reference years of 2004, 2008 and 2012. The workflow is based on Free and Open Source Software (FOSS) tools and data available free of cost. These FOSS tools used are Quantum GIS, Orfeo Toolbox, SAGA processing tool QGIS and FAO Open Foris Collect Earth. The adopted Satellite Land Monitoring System (SLMS) workflow is illustrated in Figure 3. The SLMS manual provides the detailed process how the one-time maps have been produced for each point of time under interest.

3.1.2 Emission Factors for Deforestation

i. Biomass and Carbon Stock Data

The forest inventory calculation process produces carbon density value (C ton/ha) at sample plot-level by aggregating biomass estimates relying on bio-physical tree measurements. Tree height has very high biomass prediction power in allometric equations but measuring heights for every tally tree is time consuming to measure accurately in field. For that reason, every 5th tally tree has been measured for its height during the pilot NFI campaign. Allometry is utilized to develop a height-diameter regression model and estimate tree heights. The height-diameter models by species and species groups have been assigned with plot wise model parameters. Tree-level aboveground biomass has been estimated using allometric models (Chev *etal*. 2014). The tree-level above-ground biomass values have been aggregated using the sample plot data to represent biomass density per hectare. The belowground biomass for plot is calculated using the default IPCC root-shoot ratios. The default IPCC fraction (0.47) is applied to convert biomass to carbon.

ii. Emission Factor Development

The emission factors represent emissions per hectare of land which has been converted to other land use. The national emission factors have been computed by forest strata using the recently collected pilot NFI and provincial carbon stock inventory results. Sub-alpine forest reference data, as well as carbon density data for the remaining provinces, is sourced from the KP and GB carbon stock inventories (Ali, 2017; Ali et al., 2017). The national unified densities and emission factors (Tier 2) are calculated by applying forest type areas mapped by provinces as weights to average the pilot NFI and provincial carbons inventory estimates. The mean carbon densities are also calculated for other land use classes and aggregated as national level averages by the climatic zones.

Figure 2: **Forest Inventory Measurement**

3.1.3 Land cover Change Analysis

Landcover change analysis uses supervised machine learning to classify land use based on satellite images. After image acquisition, a teaching set is created by systematic sampling of plots to be visually interpreted in terms of land use and land use change. After this an appropriate training set is defined and a Random Forest algorithm created to classify land use. The produced LULC Map is then post-processed for noise removal. Based on the polished map, final LULC maps are compiled, their accuracy estimated and appropriate provincial FREL statistics computed.

The main steps involved are technically conducted as follows:

Process 1 Satellite Imagery Acquisition and Processing

Activity data mapping is based on the LULC classification using Landsat imagery (5/7/8) for each of the reference years. Terrain corrected Level 1 (L1T) satellite imagery products[3] have been used. Top of Atmosphere (TOA) correction has been carried out using Dark Object Subtraction (DOS) algorithm to convert at-sensor radiance to Top-of-Atmosphere Reflectance. Atmospherically (and topographically) corrected image bands are stacked (concatenated) to generated composites (natural colour, VNIR, SWIR) for

[3]USGS Glovis (https://glovis.usgs.gov/next/#)
EarthExplorer (https://earthexplorer.usgs.gov/)
USGS Landsat Look (https://landsatlook.usgs.gov/viewer.html)

further analysis. Individual image scenes are stitched together (mosaicked) to cover one province or territory.

Process 2 Systematic Sampling Design and LULC Interpretation

Very High-Resolution (VHR) satellite imagery available in Google Earth are used as reference data when producing LULC maps and verifying their accuracies with visually interpreted and multi-temporal systematic plots using Open Foris Collect (**Error! Reference source not found.**). Total 11731 visual s quared plots with 50x50-meter dimensions (**Error! Reference source not found.**) have been sampled and visually interpreted as subsets of 10', 5', 2.5' and 1.25' (arcminute) systematic grid as needed to get better representation for all the major land use and cover types.

Process 3 Designing Sample Set for Image Training

Satellite image classification has been carried out using the Orfeo Toolbox classifier tool. A representative training set sample with regions of interest (ROI) have been selected by the operators for training image pixels for LULC classification.

Process 4 Image Classification

Image classification has been conducted using machine learning algorithm Random Forests. Random Forests is a non-parametric regression model capable of using continuous and categorical data.

Process 5 Post Classification Processing

Post classification processing has been applied to remove noises such as 'salt and pepper' effects of individual classified pixels. This is often done by "sieving" isolated pixels and replacing them with the classification of surrounding majority class pixels. Threshold for sieving is defined as 0.5 ha, which is the minimum continuous forest area threshold. The same threshold is applied for deforestation areas before accuracy assessment and area estimation.

Process 6 Accuracy Assessment and Area Estimation

Accuracy assessment and area estimation of the LULC map classes have been 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. Area estimates and accuracy are then inferred by analysing the samples (Olofsson et al., 2014).

Process 7 Land Use Change Assessment

Deforestation activity data generation is based on the visual plots interpreted for the LULC statistics and analysed with GIS raster analysis operations. A hotspot

layer indicating the potential locations for deforestation is produced in order to calculate statistics how much area changes there have been from forest to other land use categories. The area adjusted statistics concerning deforestation area has been acquired by applying the error adjustment with the LULC systematic visual plot observations and some additional randomly sampled visual interpretation plots (over 1600 plots) over the deforestation hotspot areas. The error-adjusted deforestation estimates are calculated following methodological guidance and formulas by Olofsson et al. (2014). The deforestation area proportions (percentages) by forest types have been derived by using the hotspot map and forest stratification.

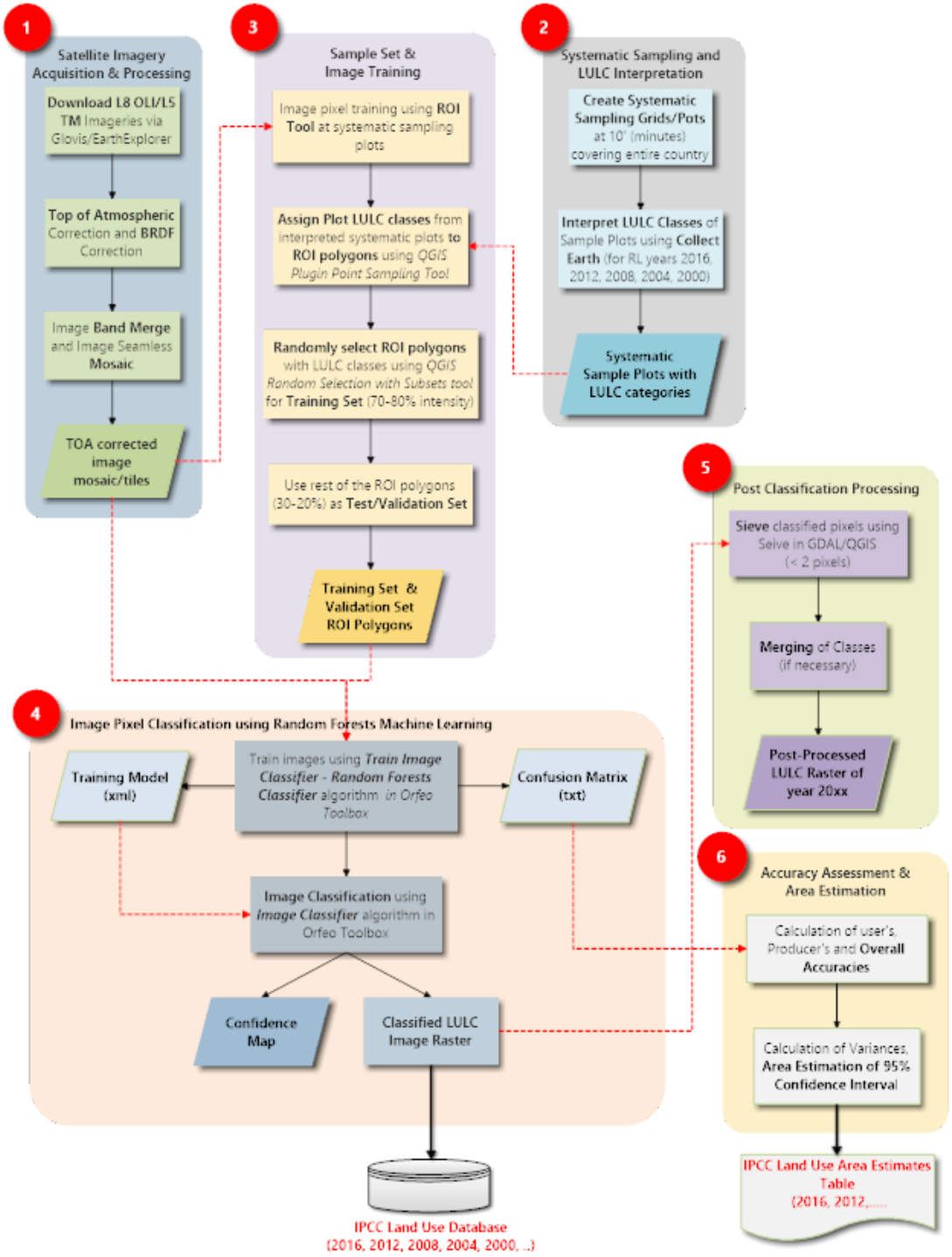


Figure 3: Design of Operationalized system for forest land assessment

3.1.4 Reference Period

The national FREL for Pakistan is developed by producing land use and cover maps with time-series analysis for 2004-2012 due to the limited reference data available for the accuracy assessment and error-adjustment before the year 2004.

3.1.5 Reference Emission Calculation

The sample plot-based forest carbon stock assessment process involves a modelling chain with the following critical steps and potential error sources:
1) Field measurements and data entries;
2) Height modelling for individual trees;
3) Allometric biomass modelling of AGB for individual trees; and
4) Applying defaults root-shoot ratios to estimate BGB

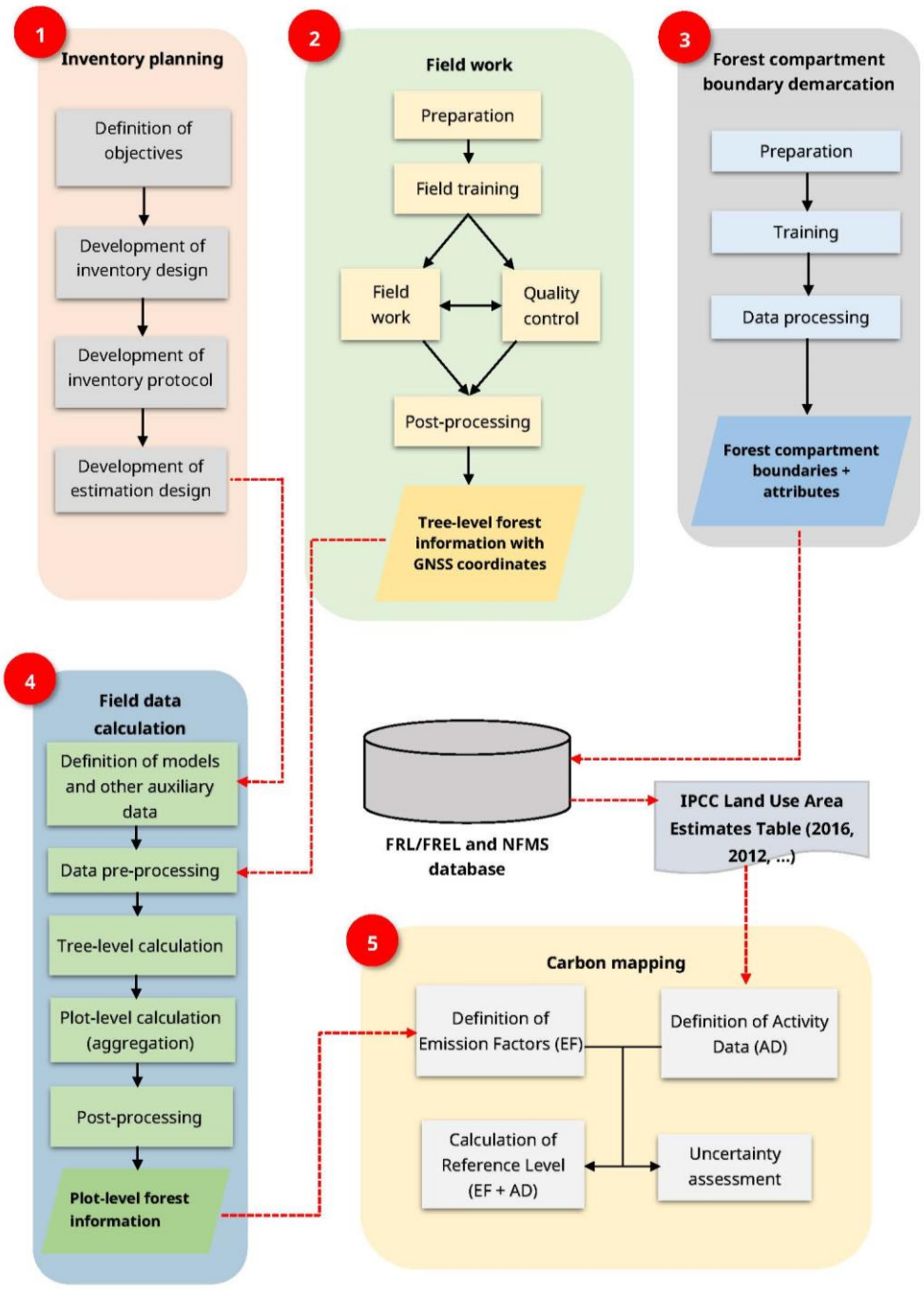


Figure 4: Design of Operationalized system for Emission Calculation

3.1.6 Emission calculation from deforestation

Deforestation converts forest land into another land use category. The emission factors represent emissions per hectare of land which has been converted to other land use. The national emission factors have been computed by forest strata using the recently collected pilot NFI and provincial carbon stock inventory results. Table 3 indicates the formula that have been used to derive the emission factors by forest strata. Sub-alpine forest reference data, as well as carbon density data for the remaining provinces, is sourced from the KP and GB carbon stock inventories (Ali, 2017; Ali et al., 2017).

Table 3 Emission factor calculation formula for deforestation.

	Term	**Variable definition / Formula**
Forest converted to other land	A	Forest carbon density, mean AGC+BGC, (ton C/ha)
	B	Other land carbon density, mean AGC+BGC (ton C/ha)
	E_{FN}	(A – B) x 44/12
	E_{FN}	**Emission factor (ton CO_2-e/ha)**

The national unified densities and emission factors (Tier 2) are calculated by applying forest type areas mapped by provinces as weights to average the pilot NFI and provincial carbons inventory estimates. The mean carbon densities are also calculated for other land use classes and aggregated as national level averages by the forest types as per table 4.

Table 4 National Unified Densities and Emission Factors (Tier 2)

Forest type	**N:o clusters**	**Mean Carbon Density (C ton/ha)**	**Emission Factor, Deforestation (CO_2-e ton/ha)**
Littoral and swamp forest (Mangroves)	-	5.2	14
Thorn	-	7.8	23
Riverine	-	19.0	65
Scrub	-	12.8	36
Pine	-	31.6	105
Moist Temperate	-	99.5	359
Dry Temperate	-	41.6	147
Sub-Alpine	-	29.1	101

Irrigated Plantation	-	20.8	71
Other land (tropical)	-	1.4	-
Other land (sub-tropical)	-	3.0	-
Other land (temperate and alpine)	-	1.6	-
Other land (farm plantation)	-	10.5	-

4. RESULTS OF THE CONSTRUCTION OF FOREST REFERENCE EMISSION LEVEL (FREL)

4.1 Estimates of Deforestation

Due to limited reference data availability, the deforestation has been assessed from 2004 onward. The average annual deforestation has been estimated up to about 12,000 hectares, while the total deforestation has been assessed as more than 94,000 hectares over the entire period of 2004-2012. **(Figure 5)**. The overall national land use map of the year 2012 is available in Annex-I:

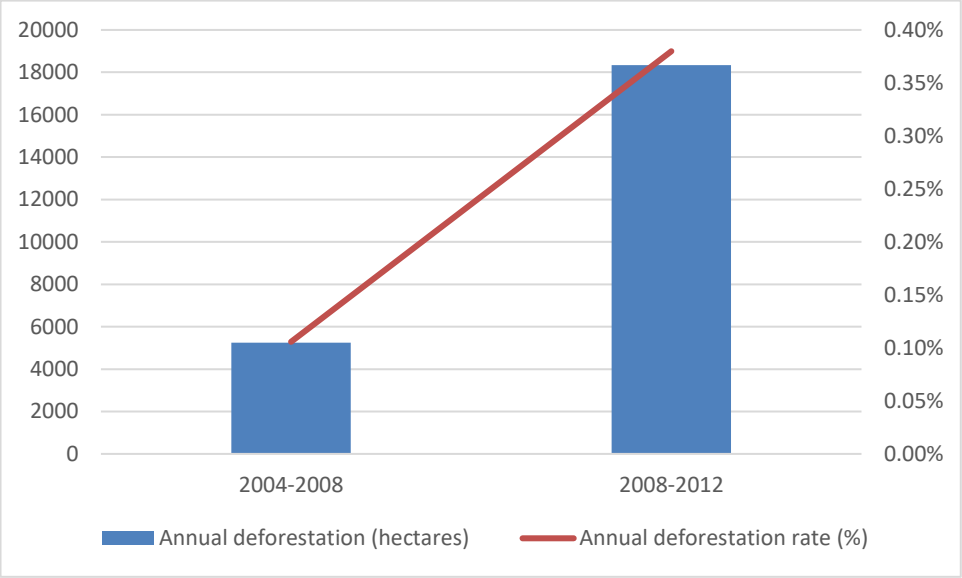


Figure 5 Annual deforestation rates in 2004-2012

Deforestation has had the highest average annual rates in scrub (25 %), thorn (14 %), pine (17 %), irrigated plantations (18 %) and dry temperate forests (13 %) (**Figure 6**).

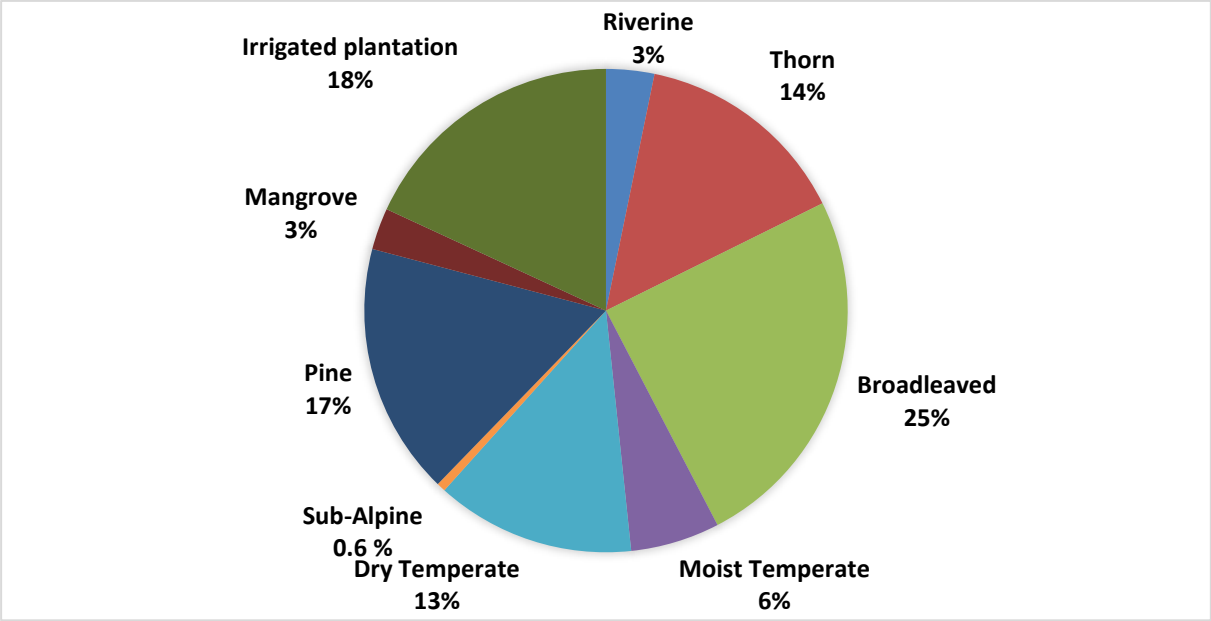


Figure: 6 Deforestation Proportion by Main Forest Strata (2004-2012)

4.2 Emissions from Deforestation

The mean annual emissions from the deforestation are 1.0 Million tons of CO_2-e between 2004 and 2012 with the increasing emission trend from deforestation. The largest share of CO2 emissions originates from moist temperate (25 %), dry temperate (23 %) and pine forests (20 %) followed by followed by riverine (2 %), scrub (10 %) and thorn (4 %) forests in 2004-2012.

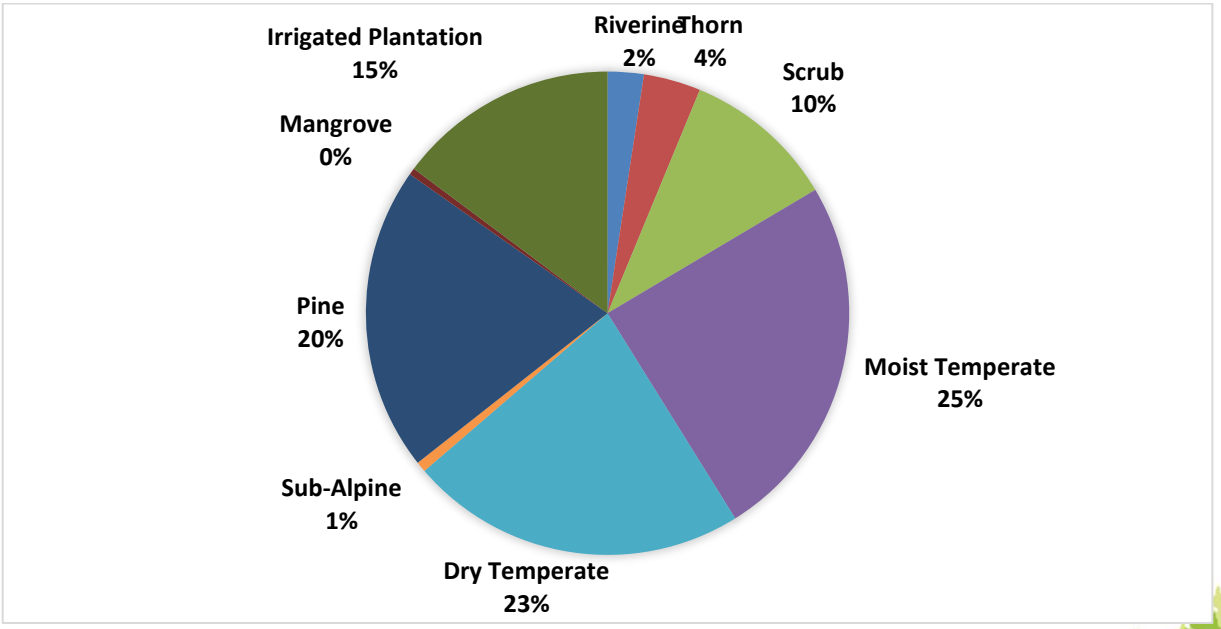


Figure: 7 Emission Proportion by Main Forest Strata (2004-2012)

The deforestation hotspot areas have been derived with the time-series analysis of two consecutive reference years. The consistency verification procedure assists in reducing false detections due to the different image radiometric and geometric properties between two sets of satellite image mosaics. Besides there may still occur some omission and commission errors with deforestation observations. VHR reference images available are not always available with constant good quality that would always allow observing canopy cover changes and producing error-adjusted area estimates with the maximum confidence.

4.3 Uncertainty Analysis

The key sources of uncertainty have been identified for both activity data and emission factors. There is some uncertainty which originates from the fact that there is no consistent carbon stock inventory data available to model the temporal variation in emissions during the different reference periods. The future projections always involve uncertainties, but it is given less weight as no FREL adjustments have been proposed.

For activity data the main sources of error are related to quality of the satellite images, temporal coverage and acquisition time (seasonality), sampling error (fragmented forest patch distribution in some areas) and random error associated to the individual visual interpretations.

Satellite imagery temporal availability and properties determine the LULC classification output quality. In case of historical Landsat data, the input image radiometric properties have been harmonised and cloud cover minimised by selecting image scenes from the post-monsoon months whenever available. Still the radiometric properties and terrain shadows are affected by the prevailing sun angle and topographic relief in that moment when images are captured. Also, due to limited image availability the coverage must have been augmented by accepting data with ± 2-year temporal difference in relation to a respective reference year.

In tabular form, national level uncertainty analysis of Activity Data can be summarized as follows:

Uncertainty Estimates 2004-2008 & 2008-2012

	Deforestation (ha), 2004-2008			Deforestation (ha), 2008-2012		
Province	**Mean**	**SE**	**95 % CI**	**Mean**	**SE**	**95 % CI**
AJK	153	74	144	4914	2833	5553
BN	384	384	752	13040	13040	25559
FATA	2091	1529	2997	4366	2519	4938
KP	6798	6798	13324	412	290	568
GB	0	0	0	797	452	887
ICT	217	59	115	856	602	1181
PB	1785	773	1515	25866	14822	29052
SD	8376	7529	14757	23130	13005	25490
TOTAL	19804			73381		

4.4. Constructed National Forest Reference Emissions Level

The proposed FREL is 1.0 Mt CO_2-e after the assessment of national circumstances and development scenarios that can potentially impact the future forest carbon emissions. The effects of future changes in national circumstances are well captured by the projections for 2012-2022 and all the upward adjustment justification criteria are not complied. The largest share of CO2 emissions originates from moist temperate (25 %), dry temperate (23 %) and pine forests (20 %) followed by irrigated plantations (15 %), scrub (10 %) and thorn (4 %) and riverine (2 %) forests in 2004-2012 (Figure 8).

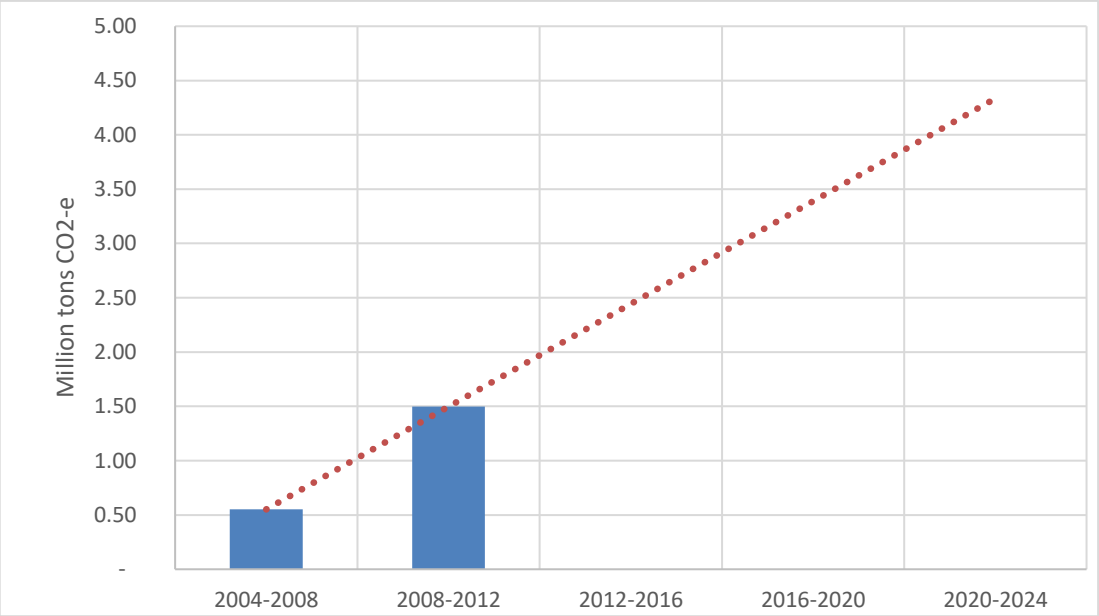


Figure 8 Mean annual emissions (Mt CO_2-e) from deforestation (2004-2012) and projection (2012-2022) at national level

5. OPPORTUNITIES FOR IMPROVEMENT

5.1 Improvement of Activity Data

In terms of spatial and spectral resolutions, there are several alternatives to Landsat 8 datasets for continuous monitoring applications. However, in terms of consistency in data coverage, availability (both current and future) and free/low cost accessibility, only Sentinel-2 (Multispectral Instrument) can be considered as a viable option. The following alternative VHR image options could be considered to provide data for accuracy assessment and area adjustment purposes:

• The recently launched (on 9 July 2018) Pakistan's own PRSS-1 Earth Observation Satellite with optical sensor capable of 1 m (3 foot) spatial resolution24 has service lifespan of 7 years and was launched to provide data for China-Pakistan Economic Corridor (CPEC). However, the details of the mission and its imagery products, availability are not known yet.

• Several commercial high-resolution imagery products are available to cover the territory of the Pakistan. SUPARCO has been providing Spot 4/525 images and derived products to the user's in Pakistan in lower costs. For the future monitoring, options like Spot 6/7 (1.5 m resolution) may be acquired through SUPARCO in subsidised cost to the provinces to implement SLMS monitoring.

• For real/near real time monitoring of smaller forest areas sUAV (small Unmanned Aerial Vehicle) commonly known as drones (flying at height less than 200 m) can be used to take nadir photographs of the monitoring area to create true color ortho-mosaics to assess the changes in forest coverage as well as canopy structure to monitor the degradation. Commercial multi-rotor sUAVs have lower endurance, flying up to 30 mins in a mission, covering about 2~5 square kilometres. While fixed winged sUAVs have endurance of 60-120 mins covering 10-20 square kilometres to acquire single run image data of very high resolution 20 cm.

• Advanced active remote sensing techniques such as LIDAR (Light Detection and Ranging) based airborne remote sensing in model-based inventories can assist in accurate collection of tree height and density information, which provides indication for the level of forest degradation over larger areas more cost-efficiently than drone systems. As a co-benefit, LIDAR can be used for producing accurate terrain height models and inventory data for forest management planning.

5.2 Improvement of Forest Emission Factors (Carbon Stock)

The second phase sampling units have been visited in field to measure above- and belowground carbon stock among other variables using the developed NFI field measurement protocol as reference. These same plots are recommended

to remeasured as permanent sample plots with 3-year intervals to assess growth, regeneration and disturbance rates. The NFI plot network should be amended to provide better statistical representation for all the major and forest sub-strata in the future. The same systematic reference grid layout and methodology should be followed in KP and GB, as well.

There should be continued efforts for more systematic and intensive collection of permanent NFI sample plot data for growth data and biomass yield models to cover the most prevailing forest type. There is already a representative selection of allometric biomass models existing for the temperate forests, but it is recommended to develop biomass models for the most common tree species in other forest strata. The recently collected carbon stock inventory datasets provide guidance in prioritising the target species. To achieve the Tier 3 targets, allometric models can be improved potentially without intensive destructive sampling campaigns, e.g. by applying the terrestrial LIDAR measurement systems to determine volume of stems and canopies of the representative standing trees.

More localized Tier 3 methods rely on local models and data adopting a systematic carbon stock and regular disturbance monitoring conducted at the lowest forest management level of natural and plantation forest compartments. The systematic data collection efforts through the NFMS and corresponding provincial systems are also required to have consistent timber, fuelwood harvesting and disturbance records from the forest compartments and REDD+ project areas in the future. Once parameter data is available simulation models can be used as a supporting approach to model the carbon stocks and fluxes in forest biomass, soil organic content, and wood product chains.

5.3 Inclusion/Exclusion of other REDD+ Activities

Forest degradation requires the emission factors for forests remaining as forests, which cannot be accounted without reliable multi-temporal measurements. Currently, there is no full nationwide coverage for forest growth, wood removal and disturbance data to produce reliable estimates for annual forest degradation rate to assess the levels of degradation and carbon stock enhancement. Carbon stock enhancement takes place through forest restoration (afforestation, reforestation and natural regeneration) and forest growth, but there is very limited growth research and modelling base for accounting emission removals from these activities.

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ANNEX-I LAND USE AND COVER MAP 2012 OF PAKISTAN