Ministry of Climate Change
Government of Pakistan

DEVELOP FOREST REFERENCE EMISSION LEVELS/FOREST REFERENCE LEVEL AND NATIONAL FOREST MONITORING SYSTEM, MEASUREMENT, REPORTING AND VERIFICATION SYSTEM FOR REDD+

National Forest Monitoring System – Measuring, Reporting and Verification

Final Report

December 2020

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National Forest Monitoring System – Measuring, Reporting and Verification

FINAL REPORT

ABBREVIATIONS

AD	Activity data
AJK	Azad Jammu & Kashmir (autonomous territory)
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BGB	Belowground Biomass
BGC	Belowground Carbon
BN	Balochistan (province)
CD	Compact Disc
CO_2	Carbon Dioxide
COP	Conference of Parties
CP	Conference of Parties (Decision references)
CSO	Civil Society Organization
CSV	Comma-separated Values
DB	Database
DBH	Diameter at Breast Height
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DVD	Digital Versatile Disc
EF	Emission Factor
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
FAQ	Frequently Asked Questions
FATA	Federally Administered Tribal Areas
FBR	Federal Board of Revenue
FD	Forest Department (provincial)
FOSS	Free and Open Source Software
FPIC	Free, prior and informed consent
FREL	Forest Reference Emissions Levels
FRL	Forest Reference Levels
FSMP	Forestry Sector Master Plan
GB	Gilgit-Baltistan (autonomous territory)

GCISC	Global Change Impact Studies Centre
GCP	Ground Control Point
GDEM	Global Digital Elevation Model
GHG-I	Greenhouse Gas Inventory
GIS	Geographic Information System
GOP	Government of Pakistan
GPS	Global Positioning System
GUI	Graphical User Interface
ha	Hectare (1 ha = 10,000 m^2)
HR	High Resolution
ICIMOD	International Centre for Integrated Mountain Development
ICT	Islamabad Capital Territory (federal capital territory)
INGO	International Non-Governmental Organization
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
IUCN	International Union for Conservation of Nature
km / km^2	Kilometer / Square kilometer (1 km^2 = 1,000,000 m2)
KP	Khyber Pakhtunkhwa (province)
LCCS	FAO's Land Cover Classification System
LiDAR	Light Detection and Ranging
LULC	Land Use Land Cover
LULUCF	Land Use, Land Use Change and Forestry
MBIGS	Multiple benefits, impacts, governance, safeguards
MMU	Minimum mapping unit
MOCC	Ministry of Climate Change
MOE	Ministry of Environment
MMRV	Monitoring & Measurement, Reporting and Verification
MRV	Measurement, Reporting and Verification
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
NCCA	National Climate Change Authority

NRP	National REDD+ Program
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NGO	Non-governmental Organization
NSC	National REDD+ Steering Committee
NSDI	National spatial data infrastructure
NTFP	Non-Timber Forest Product
NUST	National University of Sciences and Technology (NUST)
OIGF	Office of Inspector General of Forests
OBIA	Object Based Image Analysis
OGC	Open Geospatial Consortium
OLI	Operational Land Imager
O&M	Operationalization and Maintenance
PAMs	REDD+ Policies and Measures
PES	Payment of Ecosystem Services
PB	Punjab (province)
PFI	Pakistan Forest Institute
PSU	Primary Sampling Unit
QA	Quality assurance
QC	Quality control
QGIS	Quantum GIS (Open Source GIS Software)
REDD	Reducing Emissions from Deforestation and Forest Degradation
REDD+	Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
RF	Removal Factor
ROI	Regions of Interest
R-PP	Readiness Preparation Proposal
RS	Remote Sensing
R&D	Research & Development
SAGA	System for Automated Geoscientific Analysis

SAR	Synthetic Aperture Radar
SCP	Semi-Automatic Classification
SD	Sindh (province)
SECP	Securities & Exchange Commission of Pakistan
SIS	Safeguard Information System
SLMS	Satellite Land Monitoring System
SOP	Survey of Pakistan
SPOT	Satellite Pour l'Observation de la Terre (French satellite image provider)
SSL	Secure Sockets Layer
SSU	Secondary Sampling Unit
SUPARCO	Pakistan Space and Upper Atmosphere Research Commission
SWIR	Shortwave Infrared
TIRS	Thermal Infrared Sensor
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	The United Nations Framework Convention on Climate Change
US	The United States of America
USGS	US Geographical Survey
UTM	Universal Transverse Mercator (coordinate system)
VHR	Very High Resolution
VI	Visual Interpretation
VNIR	Visible and Near-infrared
VPN	Virtual Private Network
WCS	The Open Geospatial Consortium Web Coverage Service Interface Standard
WG	Technical REDD+ Working Group
WFS	Web Feature Service
WMS	Web Map Service
WWF	World Wildlife Fund

EXECUTIVE SUMMARY

A National Forest Monitoring System (NFMS) has two main functions: a 'monitoring' function and a 'Measuring, Reporting and Verification (MRV)' function. The "monitoring" function of the NFMS is primarily a domestic tool to allow countries to assess a broad range of forest information, including the REDD+ activities. The MRV function for REDD+, on the other hand, refers to the estimation and international reporting of national-scale forest emissions and removals. MRV has three main components, or 'pillars':

1) Satellite land monitoring system (SLMS),

2) National forest inventory (NFI), and

3) National greenhouse gas inventory (GHG-I).

The SLMS and NFI pillars are used to provide inputs supporting the third pillar – the GHG inventory for the forest sector.

Under the NFMS development Parties need to develop progressively and operationalize these three pillars over the three phases of REDD+, and align them with the monitoring function. The three phases are i) readiness, ii) implementation and iii) result-based payments. By the third phase of REDD+ Pakistan must have a fully functional NFMS-MRV system.

The three phases of REDD+.

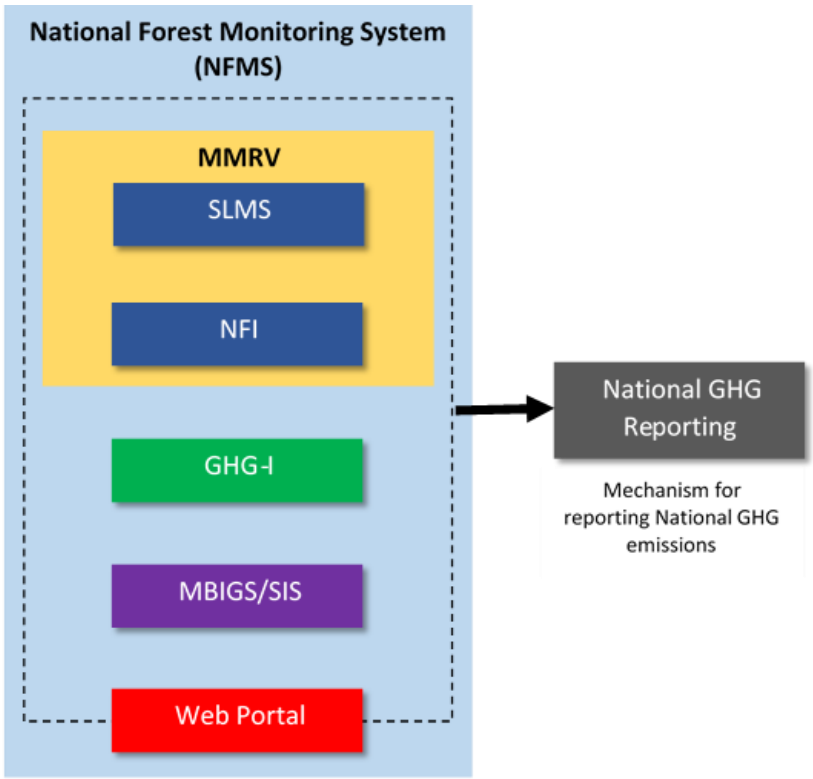
REDD+ Measuring, Reporting and Verification (MRV) forms a core function of the NFMS. It should provide data and information that are transparent, consistent over time, and are suitable for measuring, reporting and verifying anthropogenic forest-related emissions by sources and removals by sinks, forest carbon stocks and forest-area changes resulting from the implementation of the activities. The effectiveness of the REDD+ strategies and interventions can be measured and prioritized among the most significant emission sources reported and verified independently. NFMS with MRV systems are to be consistent with guidance on measuring, reporting and verifying nationally appropriate mitigation actions by developing country Parties agreed by the Conference of the Parties, taking into account methodological guidance in accordance with Decision 4/CP.15.

National REDD+ organisation and NFMS institutional roles

The National Thematic Working Groups (WGs) to 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) to take decisions on REDD+ with validated data and information. In early stages of REDD+ implementation, the WGs should be mandated to discuss about safeguard implementation, stakeholder engagement, NFMS, FREL/FRL, SIS, governance and management, REDD+ pilot projects, benefit sharing mechanisms and should evolve to incorporate any emerging issues.

NFMS for Pakistan is designed to integrate MRV functions of the SLMS and NFI along with GHG-I. The NFMS for Pakistan also includes information repository for MBIGS linked to safeguards information system (SIS) to incorporate local knowledge into national monitoring and provide participatory inputs to validate information. The system enables accounting the MBIGS matters defined as the minimum reporting contents and encapsulate participatory monitoring mechanisms as its basic component to facilitate inputs from the local communities. A national forest carbon registry system serves as a tool to register REDD+ projects and tracking availability of the certified carbon credits.



The National Climate Change Authority (NCCA)[1] will be responsible to lead the design and coordinate technical implementation of the NFMS, including the SLMS, NFI, GHG-I components linked to carbon registry and MBIGS linked to SIS. The Provincial REDD+ Management Units are responsible for operational coordination in provinces. They coordinate though the Provincial Focal Points with NCCA when developing their provincial forest monitoring systems and draft provincial standards in conformity to the national standards. The Provincial REDD+ Management Committees comprised of multi-stakeholders take decisions and also approve budgets related to provincial REDD+ interventions.

Each involved institution is recommended to have clear roles and responsibilities, which are expected to evolve over time. The following table indicates the recommended responsible, partner and co-learning institutions associated to each core NFMS function. The recommendations have been drawn after assessing the mandates, capacities and interests for the named institutions during the provincial consultations and Thematic Working Group meetings held between January 2017 and April 2018.

[1] The functions of the National REDD+ Office will be taken over by the Pakistan Climate Change Authority established under Section 5 of the Climate Change Act, 2017.

NFMS functions and institutional roles.

Function	Responsible institution	Partner and co-learning institutions
Preparation, approval and national level monitoring of finances related to REDD+ interventions	Ministry of Climate Change National REDD+ Office (NCCA) National Steering Committee on REDD+	Provincial representatives for REDD+
NFMS/MRV Coordination	Ministry of Climate Change National REDD+ Office (NCCA) [1]	Provincial (or State) Forest Departments
NFI data production	Provincial (or State) Forest Departments	Pakistan Forest Institute
SLMS data production	Provincial (or State) Forest Departments	Pakistan Space and Upper Atmosphere Research Commission Pakistan Forest Institute
GHG-I (forest sector data)	Global Change Impact Studies Centre	National REDD+ Office (NCCA)
MBIGS	National REDD+ Office (NCCA)	Provincial REDD+ Management Units
Independent verification, QA/QC	National REDD+ office	Pakistan Space and Upper Atmosphere Research Commission, Pakistan Forest Institute, Survey of Pakistan, International and National Organizations
NFMS Database and Web Portal Hosting	Global Change Impact Studies Centre	Ministry of Climate Change
Data Ownership (primary data)	Provincial Governments	Provincial (or State) Forest Departments
Data Custodianship	Global Change Impact Studies Centre	Ministry of Climate Change
Training and capacity-building	Pakistan Space and Upper Atmosphere Research Commission (SLMS) Pakistan Forest Institute (NFI)	Institute of Space Technology, Universities, International and National Organizations
Methodology and System Development	REDD+ Thematic Working group	International and National Organizations[2]

[1]The functions of the NRO will be taken over by the Pakistan Climate Change Authority established under Section of the Climate Change Act, 2017.
[2]The referred international and national organizations include WWF, IUCN, and ICIMOD among other international commercial or non-commercial entities.

Methodological Framework for Satellite Land Monitoring System (SLMS)

The REDD+ Working Group members endorsed the definition of forest and it has been notified in September 14th, 2017 as following:

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

A definition for the forest degradation was discussed in the REDD+ Thematic Working Group meeting and a recommendation has been formulated as following:

Direct human-induced long-term loss persisting for 5 years or more of at least 5 % of forest carbon stock (and forest values) since reference year (2016) and not qualifying as deforestation.

The Working Group also recommended to reassess the definition of degradation further in terms of availability of data, remote sensing and field measurement methodology to quantify proxies of forest variables to estimate on carbon stock/forest values.

Harmonization of existing land-use categories classes by the provinces with the 6 IPCC main land use categories (forestland, cropland, grassland, settlement, wetland, other land) has been conducted. Forest stratification scheme based on climatic, main ecological and sub-ecological zones has been endorsed by the WGs.

Freely available optical satellite imagery and a desktop-based workflow have been recommended for implementing Forest Land Assessment as a part of SLMS. The process workflow has been designed and implemented for developing land use and land use change activity data for the reference years in scope of FREL/FRL development.

Methodological Framework for National Forest Inventory

The NFI sampling scheme has been designed using a stratified two-phase sampling process with integration of the SLMS processes. The first phase sampling involved systematic layout of total 2954 plot locations are visually interpreted for their land use and cover categories. Out of total 128 forest classified forest locations 95 locations have been included as primary sampling units (PSUs) in the second phase sampling. The second phase sampling units have been visited in field to measure above- and belowground carbon stock among other variables using the developed field measurement protocol as the reference. These plots are recommended to remeasured as permanent sample plots with 3-year intervals to assess growth, regeneration and disturbance rates. The same systematic layout and methodology is recommended to be followed in KP and GB, as well. The NFI reference grid is used to intensify sampling to have more accurate estimates for all the forest sub-types.

Methodological Framework for Greenhouse Gas Inventory

SLMS and NFI provide all the relevant information for the national GHG-I for forestland remaining forest land, forestland converted to other land use or other land use is converted to forestland. All Forest Land in Pakistan is considered as Managed Land. 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry and Other Land Use) are to be applied as the methodological reference to ensure consistency with the FREL/FRL developed for 1996-2016. The activity data is sourced from SLMS and the emission and removal factors from NFI.

Methodological Framework for Multiple Benefits, Impacts, Governance and Safeguards

The MBIGS design has been integrated with the NFMS data model (and SIS) development processes with guidance from the REDD+ Thematic Working Groups. The defined indicators are to be collected by REDD+ intervention areas and provinces. At the beginning there must be developed a REDD+ project baseline for each MBIGS variable.

Methodological Framework for NFMS web-portal and data repository

The NFMS Web application contains different server parts built on top of Free and Open Source Software (FOSS) open source map handling applications and libraries. The system architecture, components, user interface, information contents, user right management and data exchange operations have been designed and documented. The server is located, and data has been decided to be hosted at GCISC in the 8th NSC meeting. The descriptions for data policy and sharing protocol with necessary templates are provided. The terms and conditions for using NFMS service has been defined.

Operation and Institutionalization of NFMS

Primary NFMS data ownership will be retained by the Provincial Governments. MOCC will be the custodian through GCISC (until a permanent NCCA is established in Mitigation Wing of the Pakistan Climate Change Authority, MOCC). Data Custodian will have technical role to ensure that deployed NFMS will have proper authorized data access. Furthermore, NCCA will coordinate ensuring data quality and update related issues in coordination with the Provincial REDD+ units. The Provincial REDD+ Units are provided with the mandate to collect, manage and disseminate the NFMS data pertinent to their own provincial territories.

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1. INTRODUCTION

1.1. REDD+ and National Forest Monitoring System

A National Forest Monitoring System (NFMS) is one of the elements to be developed by the Parties implementing REDD+ activities as requested in paragraph 71(c) of UNFCCC COP Decision 1/CP.16 NFMS refers to methodological framework and institutional arrangements in a country to monitor forests in the context of REDD+ and in accordance with guidance from the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC).

A NFMS system has two main functions: a 'monitoring' function and a 'Measuring, Reporting and Verification (MRV)' function. The "monitoring" function of the NFMS is primarily a domestic tool to allow countries to assess a broad range of forest information, including the REDD+ activities. The MRV function for REDD+, on the other hand, refers to the estimation and international reporting of national-scale forest emissions and removals. MRV has three main components, or 'pillars' i.e. 1) the satellite land monitoring system (SLMS), 2) the national forest inventory (NFI), and 3) the national greenhouse gas inventory (GHG-I). The SLMS and NFI pillars are used to provide inputs supporting the third pillar – the GHG inventory for the forest sector.

Under the NFMS development process, Parties need to develop progressively and operationalize these three pillars over the three phases of REDD+, and align them with the monitoring function. The three phases are i) readiness, ii) implementation and iii) result-based payments (Figure 1). By the third phase of REDD+ Pakistan must have a fully functional NFMS system in place

Figure 1 The three phases of REDD+

REDD+ MRV forms a core function of the NFMS. It should provide data and information that are transparent, consistent over time, and are suitable for measuring, reporting and verifying anthropogenic forest-related emissions by sources and removals by sinks, forest carbon stocks and forest-area changes resulting from the implementation of the activities. The effectiveness of the REDD+ strategies and interventions can be measured and prioritized among the most significant emission sources reported and verified independently. NFMS with MRV systems are to be consistent with guidance on measuring, reporting and verifying Nationally Appropriate Mitigation Actions (NAMAs) by developing country Parties agreed by the Conference of the Parties, taking into account methodological guidance in accordance with Decision 4/CP.15.

Box 1. UNFCCC COP decisions related to NFMS.

Decision 4/CP.15 (UNFCCC 2009) outlines methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. It requests developing country Parties.

a. to identify drivers of deforestation and forest degradation resulting in emissions and also the means to address these;
b. to identify activities within the country that result in reduced emissions and increased removals, and stabilization of forest carbon stocks;
c. to use the most recent Intergovernmental Panel on Climate Change guidance and guidelines, as adopted or encouraged by the Conference of the Parties, as appropriate, as a basis for estimating anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes;
d. to establish, according to national circumstances and capabilities, robust and transparent national (and sub-national) forest monitoring systems that

    i. use a combination of remote sensing and ground-based forest carbon inventory approaches for estimating, as appropriate, anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes;

    ii. provide estimates that are transparent, consistent, as far as possible accurate, and that reduce uncertainties, taking into account national capabilities and capacities; and

    iii. are transparent and their results are available and suitable for review as agreed by the Conference of the Parties.

Decision 1/CP.16 Paragraph 71 c (UNFCCC 2010) recommends "a robust and transparent national forest monitoring system for the monitoring and reporting of REDD+ activities, with, if appropriate, subnational monitoring and reporting as an interim measure, in accordance with national circumstances, and with the provisions contained in Decision 4/CP.15, and with any further elaboration of those provisions agreed by the Conference of the Parties".

Decision 11/CP.19 defines the Modalities for National Forest Monitoring Systems (UNFCCC 2013):

Para 2. Decides that the development of Parties' national forest monitoring systems should take into account the guidance provided

in decision 4/CP.15 and be guided by the most recent IPCC guidance and guidelines, as adopted or encouraged by the COP, as a basis for estimating anthropogenic forest-related greenhouse gas emissions by sources, and removals by sinks, forest carbon stocks, and forest carbon stock and forest-area changes;

Para 3. Also decides that robust national forest monitoring systems should provide data and information that are transparent, consistent over time, and are suitable for measuring, reporting and verifying anthropogenic forest-related emissions by sources and removals by sinks, forest carbon stocks, and forest carbon stock and forest-area changes resulting from the implementation of REDD+ activities referred to in decision 1/CP.16 Para 70, taking into account paragraph 71(b) and (c) consistent with guidance on measuring, reporting and verifying Nationally Appropriate Mitigation Actions (NAMAs) by developing country Parties agreed by the COP, taking into account methodological guidance in accordance with decision 4/CP.15;

Para 4. Further decides that national forest monitoring systems should:

a. Build upon existing systems, as appropriate;
b. Enable the assessment of different types of forest in the country, including natural forest, as defined by the Party;
c. Be flexible and allow for improvement;
d. Reflect, as appropriate, the phased approach as referred to in decision 1/CP.16, paragraphs 73 and 74.

1.2. National Forest Monitoring System in Pakistan

Pakistan Readiness Preparation Proposal (R-PP) has proposed NFMS as the central repository for all information pertaining to the National REDD+ Program, including both biophysical data on forest and forest land resources, emission and removal of greenhouse gases (GHG) as well as operational aspects related to the implementation of eligible activities (GOP 2013). R-PP has defined the roles of NFMS as:

a) a national forest monitoring system for emissions and removals of greenhouse gases due to avoided deforestation and forest degradation, enhancement of forest carbon stocks, conservation and sustainable management of forests; and
b) a system for providing information on how safeguards are being addressed and respected throughout the implementation of REDD+ activities

The objectives of NFMS are as following:

- To monitor forest resources of Pakistan for their sustainable management;
- To establish a national database and web portal for ensuring quality, transparency and accessibility of information related to forestry sector;

- To report to international conventions according to COP decisions and IPCC guidelines.

R-PP (GOP 2013) also recommends the purpose of NFMS as, to provide implementation support to enable all the required elements of Monitoring and Measurement, Reporting and Verification (M-MRV) defined by the COP. It also recommends requirement of additional functions that complement the implementation of the National REDD+ Program and other state functions associated with forest and forest land management including socio-economic development of the provinces. The R-PP (2013) also recommends the design criteria of NFMS to be based on guidance provided by the UNFCCC and IPCC and other sources of information.

The R-PP (2013) describes the three phased approach for the design and development of NFMS*:*

- Phase 1 Design, piloting and capacity building
- Phase 2 NFMS implementation, enhancement and capacity building
- Phase 3 Full operation of the NFMS with performance-based carbon assessment.

Pakistan has prepared a NFMS action plan (Jehangir et al. 2015) with an objective to describe activities to be undertaken to develop a robust and transparent NFMS. The action plan details a comprehensive road map for developing, establishing and institutionalization of the NFMS in the country.

2. METHODOLOGICAL FRAMEWORK AND DESIGN FOR NFMS-MRV

2.1. Institutional Framework

2.1.1. *Guiding principles for the institutionalisation process*

The NFMS institutionalization involves defining institutions and their mandates, developing and formalizing processes and methodologies in the context of the national and sub-national NFMS activities:

Institutions: Defining which institutions are involved in national and sub-national NFMS activities and what their respective roles and responsibilities are and how they should interact, how to intervene in case of challenges and who bears overall responsibility
Processes: Defining the overall process of collecting, processing, reporting and verifying data. This includes determining which role individual institutions play within this process.
Methodologies and tools: Identifying and developing standardized methodologies and tools required to collect, process and store data. The methodologies and tools are needed for NFI, SLMS, MBIGS monitoring and GHG-I.

Additionally, the resulting institutional arrangements should comply with the following criteria:

a) A solid, sustainable network of institutions with the required variety of expertise;
b) Clearly documented roles and responsibilities with a single body assigned for overall coordination;
c) Good coordination and clear lines of communication;
d) Continuity of staff and succession planning;
e) High level of ownership by the participating stakeholders; and
f) Efficient use of existing institutions and frameworks to minimize establishment and operational costs.

The institutional arrangements should establish frameworks for:

a) Formalizing mandates for data acquisition, processing and sharing amongst relevant institutions to avoid duplication of efforts;
b) Maintaining documented processes for quality assurance and quality control, so as to ensure the quality datasets (e.g. for spatial data and carbon pool measurements);
c) Continuous improvement including documentation of opportunities for improvement and process for the inclusion of such improvements;
d) Retaining skilled staff through appropriate and ongoing training and environments to encourage staff retention;
e) Securing adequate budgets to support the initial development of the MRV function as well as the ongoing operation and development.

In general terms, the main NFMS institutional roles can be classified as following:

a) National Focal Point with the overall responsibility for
   - coordinating the REDD+ MRV function and
   - liaising with the UNFCCC (Decision 10/CP.19);

b) National Institutional Body
   - to manage the work of institutions and organizations;
   - to have the overall responsibility for the coordination of administrative and technical arrangements; and
   - to ensure the overall quality of reported estimates and standardization of processes and tools

c) Mandated Institutions (national and sub-national) to perform specific tasks and provide data.

2.1.2. *National REDD+ organisation and NFMS institutional roles*

The National Thematic Working Groups (WGs) to 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) to take decisions on REDD+ with validated data and information (Figure 2). In early stages of REDD+ implementation, the WGs should be mandated to discuss about safeguard implementation, stakeholder engagement, NFMS, FREL/FRL, SIS, governance and management, REDD+ pilot projects, benefit sharing mechanisms and should evolve to incorporate any emerging issues.

The National Climate Change Authority (NCCA)[1] will be responsible to lead the design and coordinate technical implementation of the NFMS, including the SLMS, NFI, GHG-I components linked to carbon registry and MBIGS linked to SIS. The Provincial REDD+ Management Units are responsible for operational coordination in provinces. They coordinate though the Provincial Focal Points with NCCA when developing their provincial forest monitoring systems and draft provincial standards in conformity to the national standards. The Provincial REDD+ Management Committees comprised of multi-stakeholders take decisions and also approve budgets related to provincial REDD+ interventions.

[1] The functions of the National REDD+ Office (NRO) will be taken over by the Pakistan Climate Change Authority established under Section 5 of the Climate Change Act, 2017.

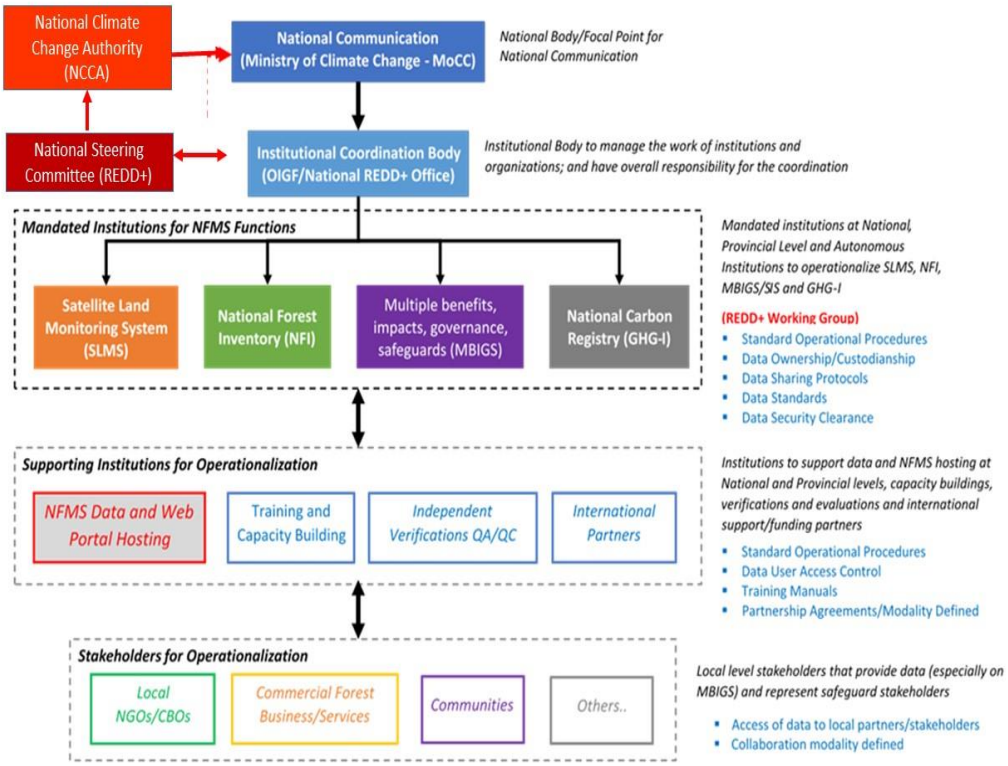


Figure 2 Institutional framework for NFMS in scope of REDD+ in Pakistan.

Each involved institution is recommended to have clear roles and responsibilities, which are expected to evolve over time. Table 1 indicates the recommended responsible, partner and co-learning institutions associated to each core NFMS function. The recommendations have been drawn after assessing the mandates, capacities and interests for the named institutions during the provincial consultations and Thematic Working group meetings held between January 2017 and April 2018.

Table 1 NFMS functions and institutional roles.

Function	Responsible institution	Partner and co-learning institutions
Preparation, approval and national level monitoring of finances related to REDD+ interventions	Ministry of Climate Change National REDD+ Office (NCCA) National Steering Committee on REDD+	Provincial representatives for REDD+
NFMS/MRV Coordination	Ministry of Climate Change National REDD+ Office (NCCA) [1]	Provincial (or State) Forest Departments
NFI data production	Provincial (or State) Forest Departments	Pakistan Forest Institute
SLMS data production	Provincial (or State) Forest Departments	Pakistan Space and Upper Atmosphere Research Commission Pakistan Forest Institute
GHG-I (forest sector data)	Global Change Impact Studies Centre	National REDD+ Office (NCCA)
MBIGS	National REDD+ Office (NCCA)	Provincial REDD+ Management Units
Independent verification, QA/QC	National REDD+ office	PFI, SUPARCO, SOP, International and National Organizations
NFMS Database and Web Portal Hosting	Global Change Impact Studies Centre	Ministry of Climate Change
Data Ownership (primary data)	Provincial Governments	Provincial (or State) Forest Departments
Data Custodianship	Global Change Impact Studies Centre	Ministry of Climate Change
Training and capacity-building	Pakistan Space and Upper Atmosphere Research Commission (SLMS) Pakistan Forest Institute (NFI)	Institute of Space Technology, Universities, International and National Organizations
Methodology and System Development	REDD+ Thematic Working group	International and National Organizations[2]

A core feature of MBIGS/SIS monitoring function is to enable incorporation of local knowledge into national monitoring and provide inputs to validate information in a participatory way. The MBIGS/SIS institutional framework defines the bottom-up inclusive arrangements to collect, compile, aggregate,

[1]The functions of the NRO will be taken over by the Pakistan Climate Change Authority established under Section of the Climate Change Act, 2017.
[2]The referred international and national organizations include WWF, IUCN, and ICIMOD among other international commercial or non-commercial entities.

analyse, validate and disseminate information. The draft Framework for Design of a Safeguard Information System in Pakistan (Climate Law and Policy/Hagler Bailly Pakistan, 2018a) suggests that the collection of data is to be carried out by the provincial REDD+ management units. This unit is expected to provide periodical evaluation reports concerning the implementation of REDD+ activities at the provincial levels.

The compilation of information from the different relevant systems and sources on how the safeguards are being 'respected' has been recommended to be carried out by NCCA[1] based on the reporting template provided for the provincial REDD+ management units. Further, it has been recommended that the NCCA through its SIS specialist lead the analysis of the quality-controlled information provided by all Provincial REDD+ Management Units with a view of determining to what extent the safeguards are being addressed and respected at national level. The draft framework envisions the involvement of third parties (e.g. NGO, CSO, academic institutions) in the quality control processes.

SIS information will be published on the specific REDD+ Safeguards Website every two years and incorporated in the national communications to UNFCCC.

2.2. Monitoring Function of NFMS

The key goal of the NFMS monitoring function is to generate reliable information to (i) support formulating, monitoring and adjusting policies related to forest and forest landscapes, (ii) inform interested stakeholders about the status of forests and (iii) report to international conventions and processes on a regular basis. NFMS includes the collection, assessment, evaluation, interpretation and reporting of data, the derivation of information as well as the monitoring of their changes and trends over time.

Monitoring sustainability of forest management and forest policies is a core objective of the NFMS monitoring function. In that sense, the criteria of sustainable forest management define the framework for national forest monitoring of Pakistan, and the indicators of sustainable forest management define the core set of attributes to be surveyed, assessed and monitored in national forest monitoring. In this context of sustainable forest management, the NFMS of Pakistan considers both the biophysical dimension of forests and the dimension of economy and society.

As a domestic tool NFMS can support monitoring a vast range of forest-related indicators. Such indicators fall beyond the monitoring of forest carbon stocks, including other parameters such as forest uses, Non-Timber Forest Products (NTFPs), forest health, biological diversity, productive, protective and socio-economic functions of forests, implementation of legal and policy frameworks, forest governance, among others. The indicators are likely to evolve over time according to the changed monitoring needs. Monitoring is the core function of the NFMS and it largely builds on the other components such as SLMS and NFI (See chapters 2.4 and 2.5).

[1] The functions of the NRO will be taken over by the Pakistan Climate Change Authority established under Section 5 of the Climate Change Act, 2017.

In scope of REDD+ the NFMS supports monitoring the performance of REDD+ demonstration activities during Phase 2 and national REDD+ Policies and Measures (PAMs) during Phase 3. The monitoring function helps to monitor with drivers of deforestation and forest degradation. In scope of the MRV system it is also necessary to discover evidence that can be linked to the direct and underlying causes altering the state of forests by accelerating or halting deforestation, forest degradation as well as afforestation and reforestation processes. Forest sector logging, transportation, export and planting records are useful to support accounting for the carbon emission removals due to sustainable management of forests (selective logging) and carbon stock enhancement (forest restoration through afforestation or reforestation).

2.3. Development of NFMS for Pakistan

Stepwise methodological approach was followed in designing, piloting and implementing the framework for NFMS in Pakistan. The methodological approaches included the steps/stages in Table 2.

Table 2 Development process for NFMS in Pakistan

Stages	Design and Development Process	Timeline
Stage 1	▪ Review of existing national and provincial system for forest monitoring ▪ Review of National Capacity and Needs Assessment by (Hussain et al. 2016). ▪ Review of Action Plan for the Implementation of the NFMS of Pakistan by (Jehangir et al. 2015)	February 2017
Stage 2	▪ Stakeholders' discussion on National Circumstances and Forest Monitoring ▪ Stakeholders' discussion on Land Cover, Activities and Forest Definition	Inception Workshop 13-14 February 2017
Stage 3	▪ Key stakeholder consultation meetings at MOCC National REDD+ Office, Provincial FDs, PFI and other stakeholders ▪ Key Informant Interviews Checklists on National Forest Inventory (NFI) ▪ Key Informant Interviews Checklists on Satellite Land Monitoring System (SLMS) ▪ Key Informant Interviews Checklists on Green House Gas inventories (GHG-I)	Visits to Provincial FD's, national and provincial stakeholders, academic institutions, other stakeholders March-June 2017
Stage 4	▪ Assessment of existing system being implemented at provincial level (KP and GB) and by supporting institutions (PFI) ▪ Assessment of international best practices	July-August 2017

	▪ Assessment of FREL/FRL submission document by REDD+ Countries	
Stage 5	▪ Framework design for SLMS and NFI ▪ Presentation and REDD+ Working Group Technical Meeting for Stakeholder's input for NFMS Design and Methodology on NFMS data needs and Institutional Framework ▪ Discussions amongst the key stakeholder groups ▪ Development and testing of processes for SLMS and NFI ▪ Development of capacity building/training contents for SLMS and NFI ▪ Training to REDD+ national and provincial stakeholders ▪ Feedback and inputs from the participating stakeholders on SLMS and NFI design	August-November 2017
Stage 6	Piloting of NFI Key informants' consultation for Users' Requirement Assessment for NFMS ▪ Design and development of NFMS ▪ Development user's documentation/ protocol/manual	October-December 2017
Stage 7	▪ NFMS Web portal development ▪ Piloting of SLMS ▪ Institutional framework consultations and endorsement ▪ Consultations for the primary and secondary information sources for deforestation and forest degradation	January-March 2018
Stage 8	▪ User's Acceptance Test for NFMS ▪ Decision for hosting of NFMS	April-May 2018
Stage 9	▪ National Capacity Building Workshop for NFMS Web portal– GHG-I ▪ Operationalization of NFMS ▪ Development of Data Sharing Protocol ▪ Installation and administrative training at the system host	June-September 2018

The NFMS for Pakistan is designed to integrate MRV functions of the SLMS and NFI along with GHG-I. The NFMS for Pakistan also includes information repository for MBIGS linked to safeguards information system (SIS) to incorporate local knowledge into national monitoring and provide participatory inputs to validate information. The system enables accounting the MBIGS matters defined as the minimum reporting contents and encapsulate participatory monitoring mechanisms as its basic component to facilitate inputs from the local communities. A national forest carbon registry system serves as a tool to register REDD+ projects and tracking availability of the certified carbon credits.

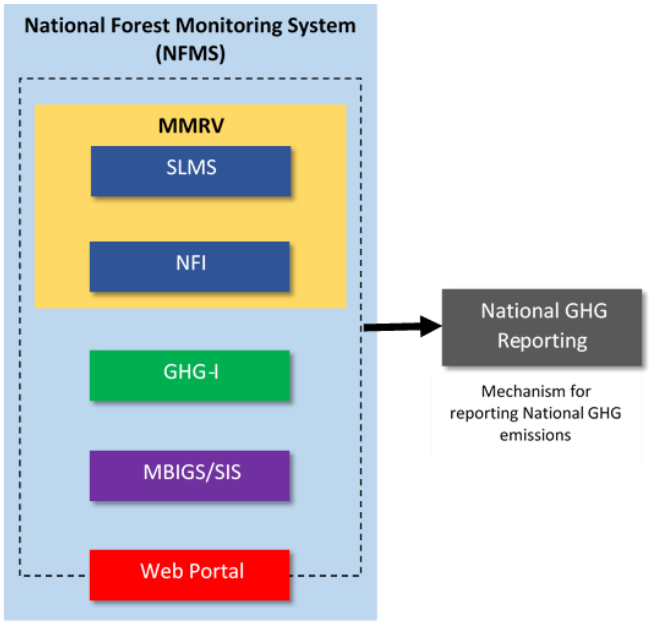


Figure 3 Framework for the NFMS design for REDD+ in Pakistan

2.4. Methodological Framework for Satellite Land Monitoring System (SLMS)

Satellite Land Monitoring System (SLMS) is aimed to collect and assess Activity Data (AD), i.e. continuous data on land use and forest area change resulting from human activities. SLMS will contribute information for the REDD+ monitoring function, as well as extends the analysis of land use land use change to the national level through wall-to-wall mapping to establish FREL/FRL. Table 3 summarises the process followed to design, implement and operationalize SLMS in Pakistan.

SLMS has been designed to track land use and cover changes. It also supports the driver and cause analysis to design REDD+ actions and monitor their effectiveness. The provincial and territorial forest departments have their field staffs to record and verify the deforestation or degradation events in field and the information is to be stored in the NFMS data repository. A forest guard or other community member informs the concerned forest officers for illegal forest actions. In many cases the detailed information about drivers and causes may come to the forest departments through the relevant sectoral agencies or

communities. In case of the development activities the concerned sectoral department or agency approaches forest department for no-objection clearance. The potential sources of such information have been identified in the WGs meeting and they are associated with each driver in Annex 2. Besides the social and electronic media may serve as an additional source regarding to the deforestation and forest degradation events.

Table 3 Design process for SLMS in Pakistan

Steps	Process	Outcome/Design Decisions
Step 1	▪ Definition of reference monitoring periods for FREL/FRL	▪ 1996, 2000, 2004, 2008, 2012 and 2016 and later at 4 years interval
Step 2	▪ National Definition of Forest and its endorsement ▪ Determining harmonized Land Use Categories ▪ Determining harmonized sub-classes for forest (forest types) ▪ Determination of Minimum Mapping Unit (MMU) ▪ Defining definition of 'Degradation'	▪ Forest Definition Notified ▪ IPCC land use classes ▪ Minimum mapping unit (0.36 hectares equalling to 2 x 2 pixels in Landsat imagery)
Step 3	▪ Compilation of existing RS data ▪ Identification of data gaps	▪ Mid-resolution Landsat imagery (cloud free) ▪ Use of +/- 2 years normalize years for data gaps ▪ Use of available secondary imageries e.g. Spot 5, Sentinel 2 and others
Step 4	▪ Defining accuracy targets and QA/QC protocols for RS interpretation and analysis	▪ >80% overall and class wise producers' accuracies with area estimation at 95% confidence Interval
Step 5	▪ Determining LULUC categories (LU conversion)	Forest remaining as Forest ▪ Cropland, Grassland, Wetland, Settlement, Other Land converted to Forest ▪ Forest converted to Cropland, Grassland,

		Wetland, Settlement, Other Land ▪ Cropland, Grassland, Wetland, Settlement, Other Land remaining as the same classes ▪ Cropland, Grassland, Wetland, Settlement, Other Land converted to others
Step 6	▪ Designing stratified sampling technique for RS classification and areas estimation ▪ Developing method for stratification of samples (visual interpretation) and QA/QC of visual interpretation method ▪ Developing protocol for visual interpretation	▪ 10'x10' systematic grids throughout the country ▪ Densified at 5'x5' and 2.5'x2.5', 1.25'x1.25' and 0.625'x0.625' at provincial levels as necessary to attain defined accuracy targets ▪ Open Foris Collect Earth GUI developed for visually interpreting ▪ Visual interpretation protocol document
Step 7	▪ Designing and piloting RS processing method (desktop based and/or cloud based) ▪ Developing protocol and methodology document for RS processing and analysis for LULUC for reference years ▪ Developing methodology for mapping and estimating forest degradation ▪ Developing methodology for mapping forest types ▪ Developing methodology for estimating aboveground woody biomass and other forest parameters ▪ Integration of NFI field data for mapping and modelling, validation and accuracy assessment	▪ Free and Open Source Software (FOSS) platform using QGIS, Orfeo Toolbox and limited Python/R Programming ▪ Non-parametric regression models such as Random Forests for land use mapping, kNN forest biomass estimation, ▪ Pixel based analysis for land use change using Multivariate Alteration Detection and other algorithms ▪ NFI (harvest/disturbance) data and complementary visual canopy analysis on VHR

		imagery for degradation assessment
Step 8	▪ Development of institutional capacity building framework for institutionalization of SLMS ▪ Development of training curricula and materials for human resources development ▪ Development of operationalization and maintenance (O&M) guideline	▪ Recommendations for Institutionalization of SLMS ▪ Training curricula and materials ▪ Operational and Maintenance protocol

2.4.1. *Key Decisions of Definitions*[1]

A key decision was made on the 'National Definition of the Forest', 'Forest stratification' and 'Other Land Use Classes' and their harmonization with existing definitions used in the country/provinces. The forest definition was endorsed by all the provincial representatives and was agreed upon to be officially notified as the National Forest Definition. The Thematic Working Groups were also consulted for the definitions for forest degradation and some recommendations were provided.

Box 2. National definition of Forest

The REDD+ Working Group members endorsed the above definition of forest as:

"A minimum area of land of 0.5 ha with a tree crown cover of more than 10 % comprising trees with the potential to reach a minimum height of 2 meters. This will also include existing irrigated plantations as well as areas that have already been defined as forests in respective legal documents and expected to meet the required thresholds as defined in the national forest definition of Pakistan."

[Notification attached in Annex 1]

The national forest definition thresholds have been defined in compliance with the Marrakesh Accords (UNFCCC COP 7, IPCC 2003b). The national forest stratification has been harmonised, consulted and endorsed by the REDD+ Thematic Working groups (Table 4).

[1] Refer Annex 1 for the process adopted for the national definition of Forest

Table 4 National forest type stratification.

Forest Stratification			
Climate Zone	**Ecological Zone**		**Density Classes**
	Main Ecological Zone	**Sub-Ecological Zone**	
1. Tropical	1.1 Littoral and swamp forest	1.1.1 Mangroves	Dense or Sparse
	1.2 Tropical dry deciduous		
	1.3 Tropical thorn forest		
	1.4 Riverain forests		
2. Sub-Tropical	2.1 Sub-tropical broad-leaved evergreen forests	2.1.1 Montane sub-tropical scrub Forests	
		2.1.2 Sub-tropical broad-leaved forests	
	2.2 Sub-tropical pine forests		
3.Temperate	3.1 Moist Temperate Forests		
	3.2 Dry Temperate Forests	3.2.1 Montane Dry Temperate Coniferous Forests	
		3.2.2 Dry temperate Juniper and Chilghoza Forests	
		3.2.3 Dry Temperate Broad-leaved Forests	
		3.2.4 Northern Dry Scrub	
4. Alpine	4.1 Sub-Alpine Forests		
	4.2 Alpine Scrub		
5. Plantation	5.1 Linear Plantations	5.1.1 Road side plantations	
		5.1.2 Railway side plantations	
		5.1.3 Canal side plantations	
	5.2 Irrigated Plantations		

2.4.2. *Harmonization of Existing Definitions*

The REDD+ WG meeting discussed on the harmonization of existing land-use categories and classes used by the provinces and recommended to be adopted for the development of national FREL/FRL. Land Use/Land Cover categories recommended by the provincial Forest Departments (FDs) are consistent and are adopted for developing land use land use change of reference years for activity data.

For other land use categories, IPCC's broader land category is considered with following definitions:

Box 3. Harmonization of Other Land Use categories

Other Land Use Categories	Definitions/Descriptions
Cropland	This category includes arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the Forest Land category, consistent with the selection of national definitions.
Grassland	This category includes rangelands and pastureland that is not considered as Cropland. It also includes systems with vegetation that fall below the threshold used in the Forest Land category and which are not expected to exceed, without human intervention, the threshold used in the Forest Land category. The category also includes all Grassland from wild lands to recreational areas as well as agricultural and silvo-pastoral systems, subdivided into managed and unmanaged consistent with national definitions.
Wetlands	This category includes land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. The category can be subdivided as "managed" and "unmanaged" according to national definitions. It includes reservoirs as managed sub-division and natural rivers and lakes as unmanaged sub-divisions.
Settlements	This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with the selection of national definitions.
Other land	This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data is available.

Deforestation is defined as the direct human induced conversion of forest to non-forest (UNFCCC) or the permanent reduction of the tree canopy cover below the minimum 10% threshold (FAO, 2015). In scope of Pakistan's first FREL submission, deforestation assessment has been based on changes in natural forests and exclude irrigated plantations, though the notified forest definition includes irrigated plantations as one of the forest types. A minimum mapping unit of 0.5 ha has been applied for the deforestation mapping. This means that less than 0.5 ha forest loss is not classified as deforestation.

FREL/FRL based on the land use and cover reporting is planned to be updated every 4 years in Pakistan. As the mapping process relies on the analysis of available satellite imagery and some changes may be observed to be only temporal. In practical terms it means that if a permanent land use and cover change could be declared when the forest has not been restored by the end of the following 4-year monitoring period. For example, if forest conversion to other land use has been observed during the period 2008-2012, it can be considered as a deforestation when no forest class is observed for the same area in 2016 maps.

In the context of greenhouse gas inventories, forest degradation refers the human-induced long-term reduction in carbon stocks be such that the forest cover, height, and area are not reduced sufficiently to reclassify the land as non-forest under the definition accepted in the Marrakesh Accords (IPCC 2003b). A definition for the forest degradation was discussed in the REDD+ Thematic Working Group meeting and a recommendation was formulated as following:

Direct human-induced long-term loss persisting for 5 years or more of at least 5 % of forest carbon stock (and forest values) since reference year (2016) and not qualifying as deforestation.

The Working Group also recommended to assess the definition of degradation in terms of availability of data, remote sensing and in-situ methodology to quantify proxy(ies) of forest variables to estimate on carbon stock and other forest variables. To be able to detect the relatively small carbon stock changes intensive field campaigns or canopy modelling with optical VHR reference data or LiDAR when using canopy cover as a proxy variable are needed. In scope of forest inventories, degradation can be observed when carbon stock variables are re-measured with regular intervals from the same inventory plots. Forest inventory plot data allows estimating carbon stocks for an area of interest and detecting changes for the period with multi-temporal observations. Forest degradation can be estimated as the balance between forest growth, wood harvests and other losses based on the forest inventory and harvest data. The latter method is demonstrated by calculating the emission/removal factors for the FREL/FRL development using pilot NFI and secondary source data for modelling.

2.4.3. *Satellite Imagery Data for LULUC and Continuous Forest Monitoring*

The territory of Pakistan is covered by 55 Landsat image scenes with free access to its archive data[1]. From 1996 until 2012 Landsat 5 TM and from the reference year 2016 onwards Landsat 8 OLI are available for SLMS. Even through Landsat satellites are imaging the Earth high temporal resolution, the images with a maximum of +/- 2-year deviation to the reference year need to be considered for having wall to wall coverage with minimal coverage of the clouds over the country. The images are acquired for the post-monsoon season months between September-November. As it applies to any other optical images, they

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

are limited to observe only the top of the canopies and only allow assessing canopy cover changes. Stereo-photogrammetry analysis using VHR optical imagery (e.g. SPOT) can allow monitoring changes in terms of canopy cover and height, but it is a costly solution for regular monitoring. Regarding to the radiometric image properties and pre-processing needs Landsat provide an advantage as one scene covers much larger land area and need smaller storage space than VHR/HR image scenes. The optical images are sensitive constantly changing light reflectance conditions in the area of interest even within a single day and between the multiple observation days. Radar data can provide indication for canopy changes but requires high technical skills and is sensitive to the changing conditions (e.g. moisture). Airborne LiDAR is accurate but a costly data source for regular monitoring purposes. The optical Sentinel-2[1] is becoming available more broadly for SLMS and allow decreasing the Minimum Mapping Unit (MMU) from 0.36 ha (2*2 pixels of 30 m resolution) to 0.04 ha (2*2 pixels of 10 m resolution) due to its 10 m spatial resolution. It is expected to be a competitive alternative to Landsat images in scope of SLMS, even though the larger image sizes require more storage and more powerful processing capacity.

Landsat 5 Thematic Mapper (L5 TM) consists of six spectral bands with spatial resolution of 30 m for Bands 1-5 and 7. Thermal Band 6 is acquired at 120 m resolution and is resampled to 30 m resolution. Each L5 TM scene is approximately 170 km north-south by 183 km east-west swath width. L5 TM has been decommissioned in 2013, therefore do not have significant usage for future forest monitoring in the national scale. Though these imageries were used to develop nation FREL/FRL under the REDD+ in Pakistan and could be used as historic references.

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) (L8 OLI &TIRS) launched jointly by the NASA and USGS entered service in 2013. Landsat 8 OLI/TIRS images consist of nine spectral bands with a spatial resolution of 30 m for Bands 1 to 7 and 9 (Table 5). The ultra-blue Band 1 is useful for coastal and aerosol studies. Band 9 is useful for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 m. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures and are collected at 100 meters. The approximate scene size is 180 km north-south by 185 km east-west.

[1] https://sentinel.esa.int/web/sentinel/missions/sentinel-2

Table 5 Spectral characteristics of Landsat 8 OLI image[1]

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Ultra Blue (coastal/aerosol)	0.43 - 0.45	30
Band 2 - Blue 1	0.45 - 0.51	30
Band 3 - Green 2	0.53 - 0.59	30
Band 4 - Red 3	0.64 - 0.67	30
Band 5 - Near Infrared (NIR) 4	0.85 - 0.88	30
Band 6 - Shortwave Infrared (SWIR1) 5	1.57 - 1.65	30
Band 7 - Shortwave Infrared (SWIR 2) 6	2.11 - 2.29	30
Band 8 - Panchromatic	0.50 - 0.68	15
Band 9 – Cirrus	1.36 - 1.38	30
Band 10 - Thermal Infrared (TIRS 1)	10.60 - 11.19	100 * (30)
Band 11 - Thermal Infrared (TIRS 2)	11.50 - 12.51	100 * (30)

[1] Source: https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

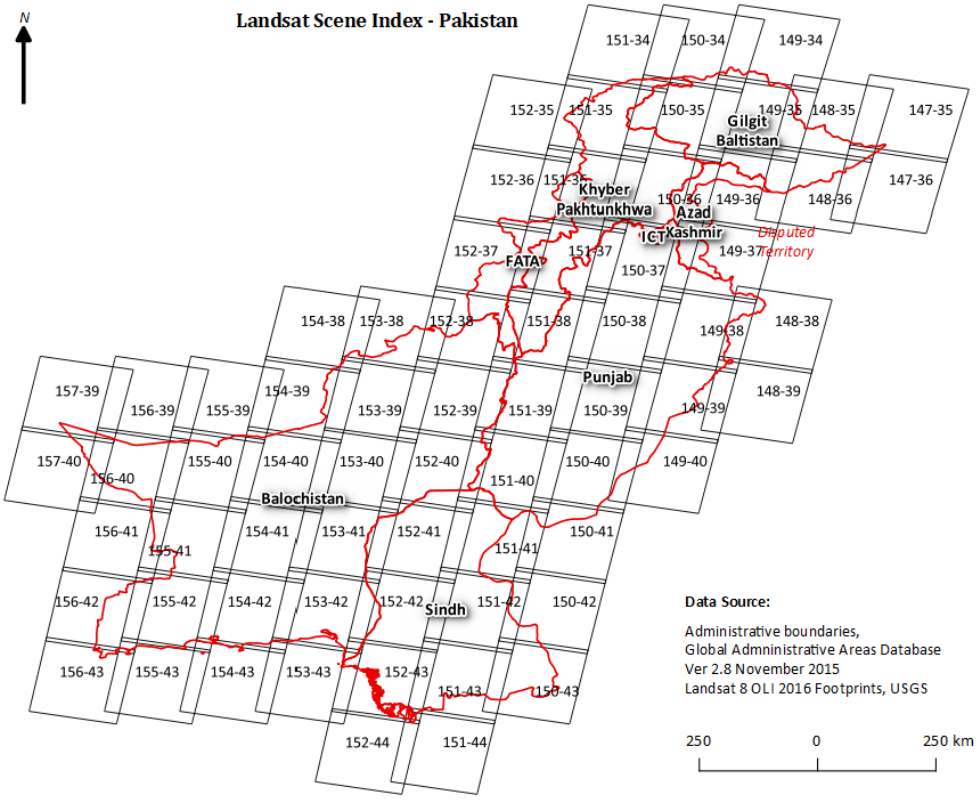


Figure 4 Landsat image scenes covering the territory of Pakistan

The spatial resolution of 30-meter in VNIR/SWIR bands with spectral range of 0.43-2.29 µm acquired in 12-bit dynamic range with improved signal-to-noise ratio provides the best option for continuous forest monitoring over large areas at the regional and national scales. With the revisit time of 16 days, L8 OLI/TIRS provides good solution for continuous monitoring over large areas. Its freely availability provides cost effective and sustainable data required for the MMRV at the national level. However, US government is considering charging for access and will be decided by the end of 2018[1]. Therefore, free accessibility may not be guaranteed for in longer term.

[1] From excerpts of news dated 24 April 2018, available at https://www.nature.com/articles/d41586-018-04874-y

Characteristics	Descriptions
Data availability	2013 onwards
Revisit time	16 days
Bands	Ultra-Blue, VNIR (G, B, R, NIR); SWIR (SWIR 1, SWRI 2); PAN; CIRRUS; TIRS (TIRS 1, TIRS 2)
Spatial resolution	Coastal/Aerosol, VNIR, SWIR and Cirrus – 30m, PAN 15m, TIRS 100m
Dynamic range of acquisition	12 bits
Image data dynamic range	16 bits
Scene Size	180 km North-South (along track) by 185 km east-west (cross-track)
Product level (for download)	L1TP (radiometrically calibrated and orthorectified using GCP and DEM)
Data format, resampling and SRS	GeoTIFF, Cubic Convolution, UTM

Advantages of Landsat 8 OLI for continuous monitoring of forest

- Spectral resolution of 0.43-2.29 µm in VNIR/SWIR bands acquired in 12-bits dynamic range allowing greater separability in land use and vegetation types
- Revisit time of 16 days allowing forest monitoring of any area at the nominal interval of 16 days
- Free access via online download archives
- Availability of higher level of products with radiometric and geometrically corrected datasets, reducing the resources and efforts of pre-processing
- Larger scene swaths covering larger areas, reducing the resources for image processing
- Continuous availability of images of the same season of the same year over large areas
- Continuity of Landsat program with Landsat 9 OLI-2/TIRS-2 planned to be launched in 2020 without any gaps in the observations with similar characteristics as that of Landsat 8 OLI/ TIRS

Disadvantages of Landsat 8 OLI for continuous monitoring of forest

- Spatial resolution of 30 m for VNIR/SWIR bands suitable for MMU of 0.36 ha which may not be suitable for sub-national monitoring in case the provincial forest definition adopts minimum area smaller than 0.5 ha (e.g. minimum area of 0.05 ha adopted by KP);
- Due to spatial resolution of 30 m, deforestation in smaller areas and degradation cannot be identified and quantified with required accuracy; and

- Requires good and high-speed internet connectivity for downloading large volumes of imagery data over defined intervals for monitoring interval period.
- Though the Landsat program only remains continuous and consistent satellite observation mission and will continue in the foreseeable future with the announced launch of Landsat 9 OLI-2/TIRS-2 in 2020, free availability of the data after 2018 is still in doubt given the US government's ongoing review of its data policy.

Alternative of Landsat 8 OLI for continuous monitoring of forest

- In terms of spatial and spectral resolutions, there are several alternatives to Landsat datasets for continuous monitoring applications (e.g. SPOT 6/7, RapidEye, DMC, Deimos, SuperView/GeoJing etc.). However, in terms of consistency in data coverage, availability (both current and future) and free/low cost accessibility only Sentinel 2 MSI could be considered as a viable option.
- The recently launched (on 9 July 2018) Pakistan's own PRSS-1 earth observation satellite with optical sensor capable of 1m (3 foot) GSD [1]is the other option. The PRSS-1 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 is not known yet.
- Several commercial high-resolution imagery products are available to cover the territory of the Pakistan. SUAPRCO has been providing Spot 4/5[2] images and derived products to the user's in Pakistan in lower costs. For the future monitoring, options like Spot 6/7 (1.5m GSD) may be acquired through SUPARCO in subsidised cost to the provinces to establish their SLMS.
- For real/near real time monitoring of smaller forest areas sUAV (small Unmanned Aerial Vehicle) commonly known as drones (flying at height < 200m) can be used to take nadir photographs of the monitoring area to create RBG (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 about 30 mins in a mission, covering about 2~5 sq.km. While, fixed winged sUAVs have endurance of 60-120 mins covering 10-20 km^2 to acquire single run image data of very high resolution 20 cm GSD. However, in case of Pakistan, civilian/commercial UAV flight missions may be subjected to security restrictions.

2.4.4. *Design of Desktop Based SLMS Workflow*

A desktop-based workflow for implementing Forest Land Assessment as a part of SLMS is designed and piloted to be implemented for MRV in Pakistan. The workflow is based on Free and Open Source Software (FOSS) tools available free of cost for downloading. These FOSS tools used are Quantum GIS, Orfeo Toolbox, SAGA processing tool QGIS and FAO Open Foris Collect Earth.

[1]https://www.dawn.com/news/1418966/pakistan-launches-remote-sensing-satellite-in-china and https://spaceflightnow.com/2018/07/09/china-successfully-launches-two-satellites-for-pakistan/

[2] Spot 4 and 5 are from the French Space Agency Centre National d'Etudes Spatiales (CNES) and are discontinued since 2015.

Limited use of programming scripting in Python/R is necessary to automate the workflow. The desktop SLMS processes workflow is shown in Figure 5.

Process 1 Satellite Imagery Acquisition and Processing

Availability of reference year archived Landsat images can be explored, and archived imageries can be downloaded from various sources using several free online tools such as

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

Terrain corrected Level 1 (L1T) imagery products are used. L1T product are radiometrically corrected and orthorectified using ground control points and Digital Elevation Model (DEM) data correct for relief displacement. L1T products are the highest quality Level 1 product and is suitable for pixel level time series analysis (USGS, 2017).

Top of Atmosphere (TOA) correction is done using Dark Object Subtraction (DOS) algorithm to convert at-sensor radiance to Top-of-Atmosphere Reflectance. DOS method is used when there is no available data on atmospheric conditions and aerosol properties at the time of image acquisition. This method assumes that within image some pixels are in complete shadow and their radiances received in the satellite are due entirely to atmospheric scattering (path radiance). This path radiance values are then subtracted from each pixel value in the image. TOA correction can be applied using QGIS SCP plugin's TOA correction.

Additionally, topographic correction (topographic normalization) is recommended to remove topographic slope shadows using a Bidirectional Reflectance Distribution Function in correction algorithm for the images in the higher mountainous regions. However, there are only limited number of tools in open source platform for image topographic normalization. Topographical correction using Normalization algorithm by (Law and Nichol, 2004) can be used without overcorrection and suitable for sampling for further classification of images. However. It should be noted that the DEM being used ASTER GDEM or SRTM DEM[1] (about 30 m resolution) may produce banding effect resulting in lower quality of corrected Landsat images. Topographic normalization can be done using SAGA (System for Automated Geoscientific Analysis) [2] Topographic Correction tool from within QGIS processing environment. Alternatively GRASS processing tool (i.topo.corr) can be used for topographic correction using C-Correction[3].

Atmospherically (and topographically) corrected image bands are stacked (concatenated) to generated MSS composites (natural color, VNIR, SWIR etc.)

[1] https://gdex.cr.usgs.gov/gdex/
[2] http://www.saga-gis.org/
[3] https://grass.osgeo.org/grass73/manuals/i.topo.corr.html

for further analysis. Individual MSS image scenes are stitched together (mosaicked) to cover a province or an area of interest.

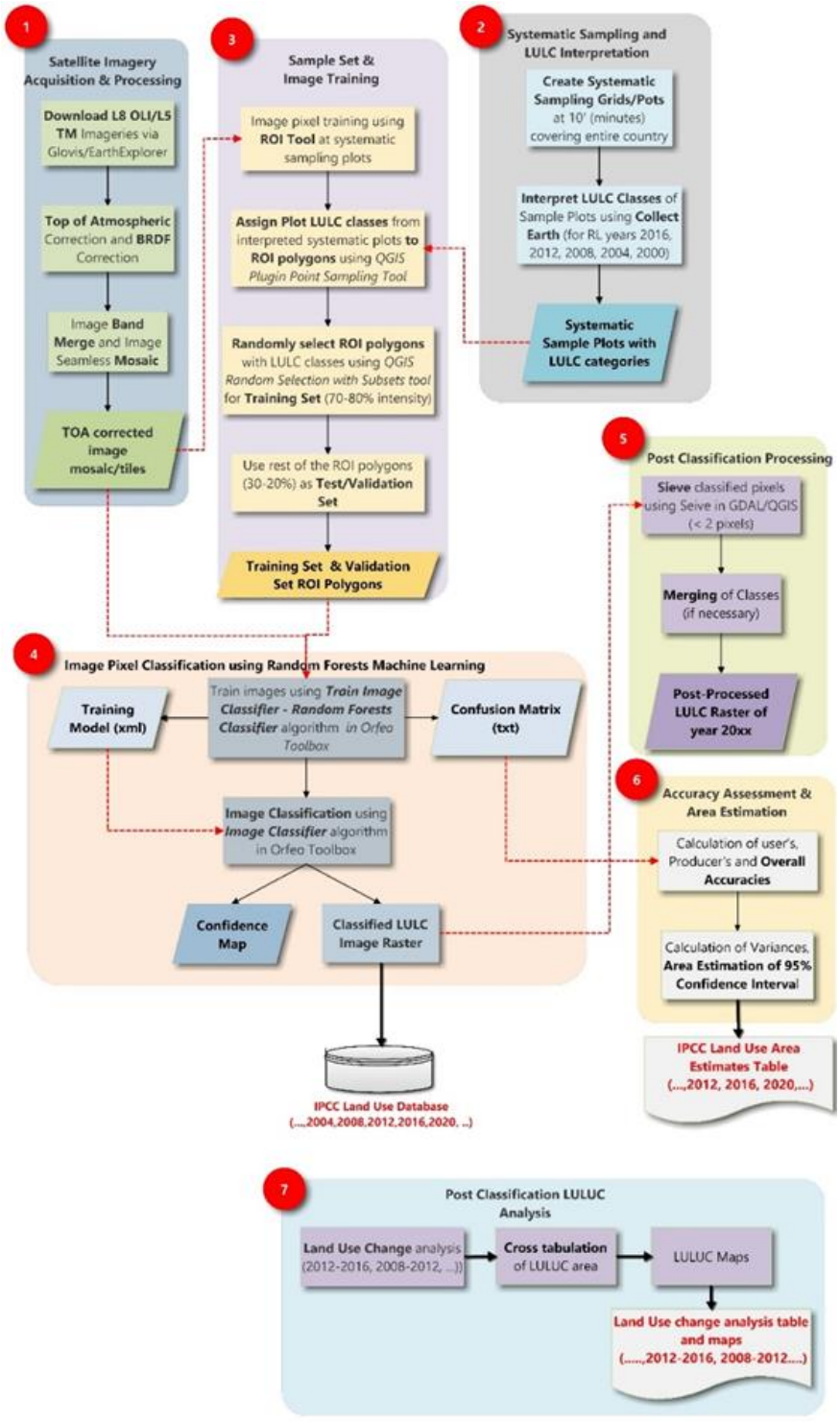


Figure 5 Workflow for desktop based SLMS for forest land and activity assessment.

Process 2 Systematic Sampling Design and LULC Interpretation

Systematic sampling grids are generated to cover the territory of Pakistan for the first phase (Phase I[1]) sampling for IPCC Land Use classes to be used for preliminary wall-to-wall land use map preparation and forest inventory design (Figure 6). The systematic grids and the sample plots are created using Open Data and Open Source Tools and is a part of desktop-based Satellite Land Monitoring System (SLMS) workflow to be implemented for REDD+ FRL/FREL and MRV in Pakistan.

Due to the previous non-availability (restrictions of use) of the recent land cover/land use spatial data for designing the sample set (stratification), independent systematic grids have been generated. The systematic sample plots are initiated from 10' x 10' grids (≈16 km x 18 km) to cover the entire territory of Pakistan. The grids can be densified to 5' x 5' (≈8 km x 9 km) or 2.5' x 2.5' (≈4 km x 4.6 km) or further to represent the subnational levels i.e. at provincial level. Grids should also be densified, if the accuracy levels of LULC product do not comply with the classification accuracy levels at 95 % confidence interval. Higher density of sample plots is expected to result in higher accuracy levels of LULC product. For the territory of Pakistan, provinces and federally administered areas the approximated number of sample units for different grid spacing are provided in Table 6.

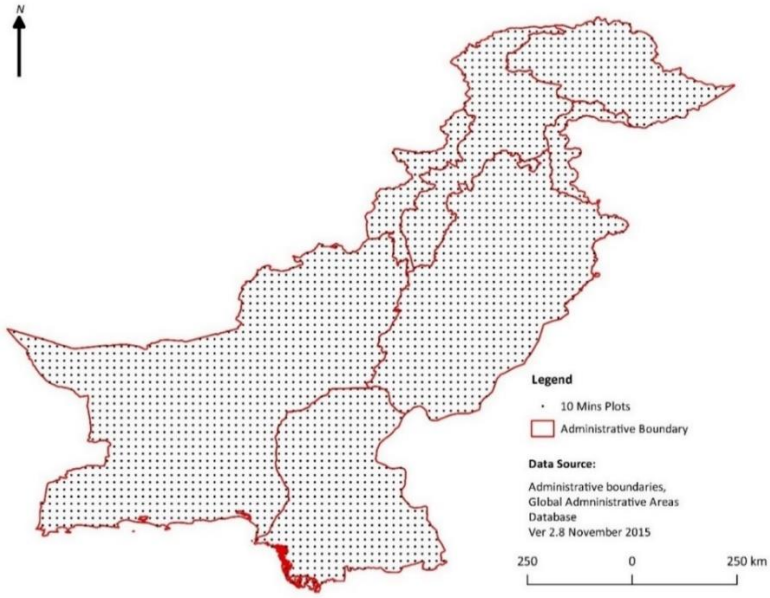


Figure 6 Systematic grid of the first phase sample plots at 10' interval (about 16 km x 18 km).

[1] The first phase sampling is based on the regular 10' x 10' (about 16 km x 18 km) reference grid points. They are assessed visually for their land use and cover using VHR imagery (Google Earth). It is followed by the second phase sampling, when a subset of the regular 10' x 10' grid point locations classified visually as forests are visited in field for ground-truthing and NFI measurements.

Systematic plots grids are created using QGIS Research Tools. These plots are further stratified using Digital Elevation Model (elevation range, slope, aspect) and forest type regions. For the initial sampling, 10'x 10' grid plots are laid out throughout the country (Figure 6).

Upon the designing of systematic sample plots, stratification of land use land cover categories and other parameters are done using visual interpretation of Very High-Resolution (VHR) satellite imagery available in Google Earth, Bing Image and Google Earth Engine platforms. These systematic sampling plots generated are visually interpreted for IPCC Land Use Classes (Forest, Cropland, Grassland, Wetland, Settlement, Other land) using customized Open Foris Collect Earth GUI data collection form. Land use classes with various other parameters for Forest (canopy cover, disturbances etc.) are collected for different reference years 1996, 2000, 2004, 2008, 2012 and 2016.

Table 6 Systematic sample plots for different grid spacing.

Provinces	Primary Sample Plot (PSU)			
	10'	7.5'	5'	2.5'
KP	268	477	1,073	4,276
AJK	48	89	194	774
FATA	90	152	354	3,901
GB	246	434	980	1,391
Sindh	459	810	1,831	7,292
Punjab	701	1,244	2,787	11,174
Balochistan	1,138	2,033	4,567	18,283
ICT	4	5	13	48
Total	**2,954**	**5,244**	**11,799**	**47,139**

Figure 7 Visual interpretation plot and sub-plots

For visual interpretation (VI), these sample plots are used as the centre (Primary Sampling Unit) for 5 x 5 (25 sub-plots) in a cluster plot configuration of 50 m x 50 m covering and area of 0.25 ha. The sub-plots are 2 m x 2 m in size.

In Figure 7 plot, 14 sub-plots fall under tree cover (i.e. 14/25 =56 %), therefore the plot has approximately 56 % tree cover.

Comparison of VI plots between reference years 2004, 2008, 2012 and 2016 present in Figure 8 shows forest cover change dynamics in Plot#8073 in AJK.

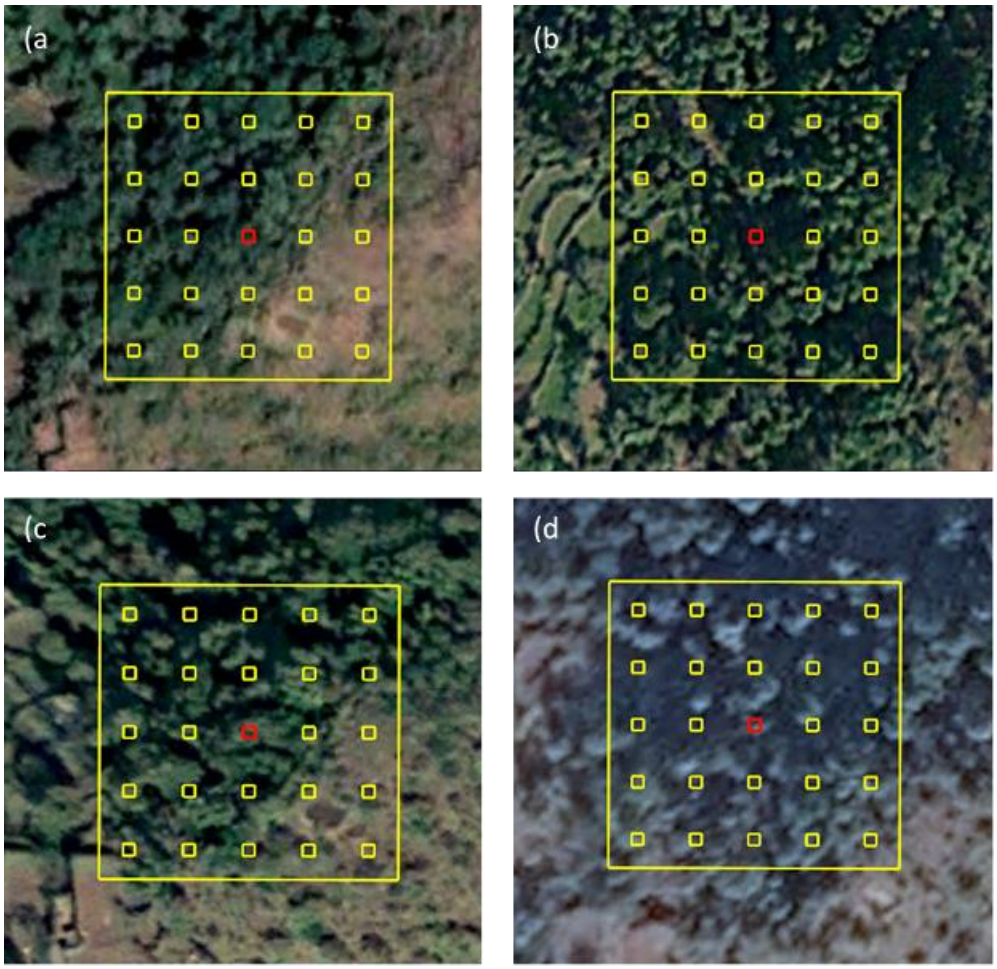


Figure 8 Forest change in Plot#8073 in AJK (a) 2004 (b) 2008 (c) 2012 and (d) 2016.

For Forest plots, sub-plots with tree cover are counted to estimate tree cover in the plot. Observable disturbances in the plot can also be interpreted in the VHR images to the extent possible. Disturbances classes used are:

- Logging
- Fire
- Grazing
- Landslide
- Tree Plantation
- Shifting Cultivation
- Construction
- Others

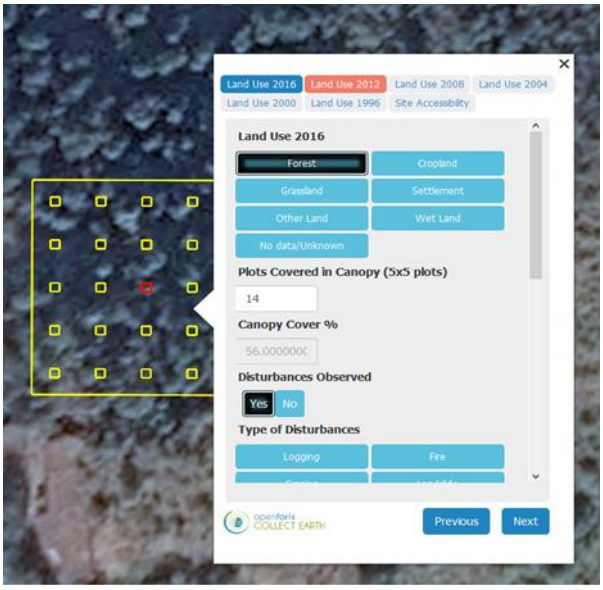
If the plot has mixed LULC, the mixed classes are also indicated.

One of the following interpreted image sources are indicated with the acquisition date of the image:

- Google Earth
- Bing Maps
- Landsat 8 OLI
- Landsat 5 TM
- Sentinel 2
- Spot 5/Spot 4
- Other VHR
- No Satellite Images Available

Accessibility categories of the plot site is also visually interpreted. The accessibility classes are:

- Accessible
- Inaccessible due to Slope
- Inaccessible due to Water Body
- Inaccessible due to Restrictions
- Inaccessible due to Other Reasons
- Unknown



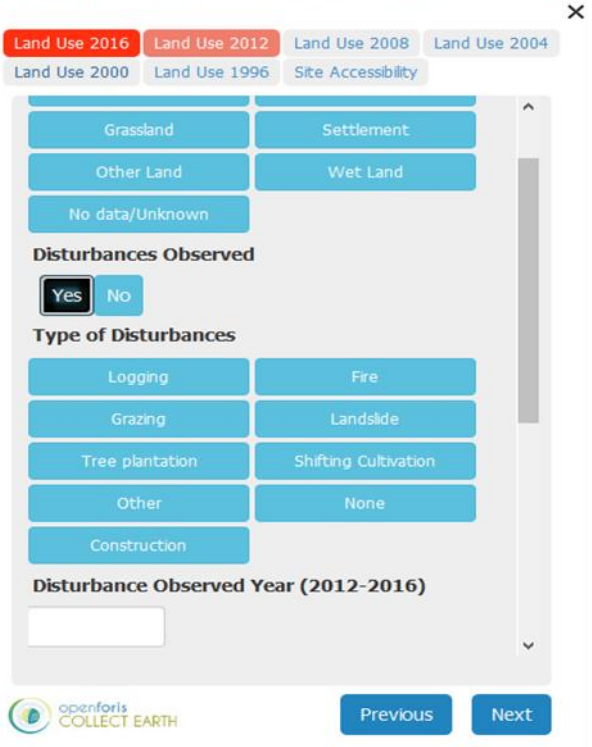


Figure 9 CollectEarth Visual Interpretation interface used for interpretation of sample plots for Phase I sampling using Google Earth.

Process 3 Designing Sample Set for Image Training

Visually interpreted points with land use classes are used as 'seeds' for generating sample sets to develop training and validation subsets. The training sets with regions of interest (ROI) are used for training image pixels for classification. The validation sets are used for independent check of the accuracy and subsequent area estimation.

Process 4 Image Classification using Random Forests

Image classification is conducted using machine learning algorithm Random Forests in QGIS. Random Forests is a classification and regression algorithm used increasingly being used to satellite image classification for creation of continuous field data such as percent tree cover, biomass, land cover type etc. Random Forests is a non-parametric regression model capable of using continuous and categorical data and is easy to parametrize, is non-sensitive to over fitting, can handle outliers in training data and also calculates ancillary information such as classification error and variable importance.

RF algorithm is based on the ensemble model that uses the results from many different models to calculate a response. In Random Forest, several decision trees are created, and the response is calculated based on the outcome of all the decisions trees. Some common applications of random forests classification include land cover and land cover change mapping. Regression applications include continuous filed mapping e.g. percent tree cover, percent shrub cover, impervious surfaces and biomass mapping.

Satellite image classification is done using Orfeo Toolbox classifier tool. The classification is done in two steps. The first step involves training of image pixels using the classification sample set and defining the depth of the 'tree', minimum number of samples in each tree, termination of regression tree and other parameters required. The first step also involves defining of maximum training sample size and validation sample size. The second step involves classification of trained pixels using previously created classifier model.

Process 5 Post Processing

Post classification processing is done 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. For the case of LULC of Pakistan, the minimum mapping unit is considered as 2 pixels (i.e. 60 x 60 m). Threshold for sieving needs to be defined accordingly. QGIS SCP plugin tool can be used for 'sieving'.

Process 6 Accuracy Assessment and Area Estimation

Accuracy assessment of LULC map classes and areas estimation of LULC classes is done using the sample of reference observations of the study area. The basic idea here is the assumption that the mapped areas of land cover (or change in 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 sample (FAO 2016; Olofsson et al., 2014). Accuracy assessment and area estimation can be done following the process prescribed by (FAO, 2016), which includes three main steps:

- design and selection of sample
- response design: interpretation of sample and decision of agreement of reference and map observations
- analysis of sample

Error matrix is constructed by 'cross-tabulating' mapped samples vs reference samples in a tabular format as shown in Table 7 (adopted from Olofsson et al. 2014).

Table 7 Population error matrix of four classes with cell entries (p_{ij})

		Reference						
		$A_{m,i}$	W_i	$A_{m,i}$	W_i	$A_{m,i}$	$A_{m,i}$	W_i
Map	Class 1	p_{11}	p_{12}	p_{13}	p_{14}	$p_{1.}$		
	Class 2	p_{21}	p_{22}	p_{23}	p_{24}	$p_{2.}$		
	Class 3	p_{31}	p_{31}	p_{31}	p_{31}	$p_{3.}$		
	Class 4	p_{41}	p_{41}	p_{41}	p_{41}	$p_{4.}$		
	Total	$p_{.1}$	$p_{.2}$	$p_{.3}$	$p_{.4}$	1		

Error matrix of sample counts for randomly selected stratified validation points n_{ij} . The total map samples in a Class i is represented by $n_{i.}$. The proportion of mapped area $A_{m,i}$ for Class i is represented by W_i, where

$$W_i = \frac{A_{m,i}}{\sum A_{m,i}}$$

The sample-based estimator for area proportion p_{ij} is given by $\hat{p}_{ij} = W_i \frac{n_{ij}}{n_{i.}}$

Where, *i* denotes the row and j denotes the column in the error matrix. For stratified random sampling designs, where the strata correspond to the map classes, error matrix may be represented in terms of estimated area proportions $\hat{p}_{ij}$.

User's accuracy of class i is $\widehat{U}_i = \frac{\hat{p}_{ii}}{\hat{p}_{i.}}$

and its complimentary measure commission error of class i is $1 - \frac{\hat{p}_{ii}}{\hat{p}_{i.}}$

Producer's accuracy of class j is $\widehat{P}_j = \frac{\hat{p}_{jj}}{\hat{p}_{j.}}$

and its complimentary measure omission error of class j is $1 - \frac{\hat{p}_{jj}}{\hat{p}_{j.}}$

The Overall Accuracy is given by $\hat{O} = \sum_{j=1}^{q} \hat{p}_{jj}$

and its estimated variance is given by $\hat{V}(\hat{O}) = \frac{\sum_{i=1}^{q} W_i^2 \hat{U}_i(1-\hat{U}_i)}{n_i - 1}$

The estimated variance for User's Accuracy by $\hat{V}(\hat{U}_i) = \frac{\hat{U}_i(1-\hat{U}_i)}{n_i - 1}$

The 95% confidence intervals are estimated as $\pm 1.96\sqrt{\hat{V}(\hat{O}_i)}$

for Overall Accuracy and $\pm 1.96\sqrt{\hat{V}(\hat{U}_i)}$ for Users' Accuracy.

The estimate of confidence interval is given by

Standard Error $\mathrm{SE}(\hat{p}_{.j}) = \sqrt{\sum_i \frac{W_i\ \hat{p}_{ij} - \hat{p}_{ij}^{\ 2}}{n_{i.} - 1}}$ of the stratified estimator of estimated proportion area.

Process 7 Land Use and Land Use/Cover Change Activity Data

Activity data generation is based on the for the LULUC statistics analysed with GIS operations. The objective is to produce a raster layer indicating the locations for class changes and their type in order to calculate statistics how much area changes there have been from one category to the other.

The forest degradation analysis is based on the visually interpreted forest plots with assigned canopy cover ratios for different years. The statistical analysis can be conducted in a spreadsheet software such as MS Excel. The mean canopy coverage changes and 95 % confidence intervals are calculated between two points of time under interest (Table 8).

Table 8 Canopy change analysis based on the visually interpreted plots for AJK. VHR imagery is not available from 1996.

Variable	2012-2016	2008-2012	2004-2008	2000-2004	2008-2016
Mean canopy change - %-units	0.1	3.7	0.2	-1.6	1.0
Plot Count	100	29	17	5	115
Standard deviation	11	14	10	2	11
Confidence interval Lower (95%)	-2.0	-1.7	-5.1	-4.3	-1.1
Confidence interval Upper (95%)	2.3	9.1	5.6	1.1	3.1

2.5. Methodological Framework for National Forest Inventory (NFI)

National Forest Inventory (NFI) has been designed and piloted to collect reliable data to estimate the Emission/Removal Factors (EF/RF) for various forest strata throughout the country. The NFI is designed considering the existing capacities of the country and the approach already being implemented Provincial Forest Departments. Following the international best practices, NFI is designed following stratified sampling to establish permanent and complementary temporary sampling plots. The development of the NFI also followed a strategic and participatory stepwise process (Table 9)

Table 9 Design process for NFI in Pakistan

Steps	Process	Outcome/Design Decisions
Step 1	▪ Creation any auxiliary information needed for designing the sample, like land use classification, updated administrative boundaries ▪ Testing different sampling possibilities. Information used as background information for sampling design ▪ Creating stratification based on proper data sources ▪ Deciding the methodologies for sampling and designing the sample.	▪ Auxiliary information for background and input information for stratification and sampling design. ▪ Stratification ▪ Ready sampling design, report ▪ List of sample plots for field measurements
Step 2	▪ Designing the inventory protocol. Includes decisions on which variables are included in field work ▪ Designing the estimation process, including allometric models and estimation calculation	▪ Inventory manual ▪ List of allometric models to be used in calculation process ▪ Decisions on the estimation and error calculations taking into consideration the sampling design
Step 3	▪ Deciding composition of field teams ▪ Selection of members for field teams ▪ Practical training for field teams ▪ Distribution of field plots for field teams and decisions on work order	▪ Field team composition ready ▪ Work schedule ready
Step 4	▪ Field plot measurements ▪ Quality control measurements ▪ Error checks on data in the office during the field work	▪ Quality checked field data

Step 5	▪ Post-processing of GPS coordinates ▪ Field plot calculation ▪ Processing of all secondary data collected from the field, e.g. pre-processing of vegetation samples from litter or shrub pools or soil samples ▪ Laboratory work different samples for determining carbon content	▪ Plot-level field data with post-processed GPS coordinates
Step 6	▪ Calculation of average carbon content on all pools for all plots ▪ Calculation of average carbon content on all pools for different strata ▪ Calculation of error estimates	▪ Field plots with carbon content for all pools ▪ Average carbon content for all strata on all pools ▪ Report on average carbon content and error estimates
Step 7	▪ Reporting on field work and results ▪ Recommendations for the future ▪ Presentation of results	▪ Report on National Forest Inventory results and recommendation

2.5.1. *NFI integration with SLMS*

The sampling design of the National Forest Inventory (NFI) is developed in conjunction with the SLMS process using remote sensing satellite imageries and ancillary data. There are various sampling design schemes, but the selection of specific design should be a compromise between accuracy, limitations and available resources. Basic rule is to minimize the error with the available resources in terms of financial, time and technical capacities. Usually stratification is a good way to optimize the sampling efforts. Stratification enables the same level of accuracy for carbon stock estimates with less sample plots. The stratification can be done using a combination of data sources which are related to the main variable of interest, in this case aboveground carbon.

The NFI sampling scheme is designed using stratified two-phase sampling process with integration of the SLMS processes. The 10'x10' (or 5'x5'/2.5'x2.5'/1.25'x1.25) systematic grid which have been created for LULC visual interpretation for the first phase (Phase I) sampling. The second phase sample (Phase II) was selected from the Phase I sample based on the accessibility criteria. The stratification is done based on land use land cover classification. Additional data sources were used for stratification, as needed, e.g. elevation information to ensure accessibility to plots.

The first phase sampling involved layout of systematic plots at 10' x 10' throughout the territory of Pakistan and visual interpretation of the plots for land use stratification for the year 2016. Total of 2,954 plots were laid out to represent land use pattern of the year 2016 *(refer* Table 10 *a*nd Figure 10*)*. From these first phase plots, out of total 128 forest visually classified forest points 95 points

have been included as primary sampling units (PSUs) in the second phase sampling in the field for NFI after analysing the accessibility conditions.

Table 10 Distribution of Phase I plots

Land Use	GB	KP	FATA	AJK	ICT	PB	SD	BN	Total
Forest	5	19	16	19	1	26	12	30	128
Cropland	1	72	3	6	3	403	171	61	720
Grassland	33	65	40	14	0	86	123	197	558
Wetland	2	3	2	1	0	7	12	6	33
Settlement	0	2	1	2	0	32	11	3	51
Other Land	205	107	28	6	0	147	130	841	1464
Total	**246**	**268**	**90**	**48**	**4**	**701**	**459**	**1138**	**2954**

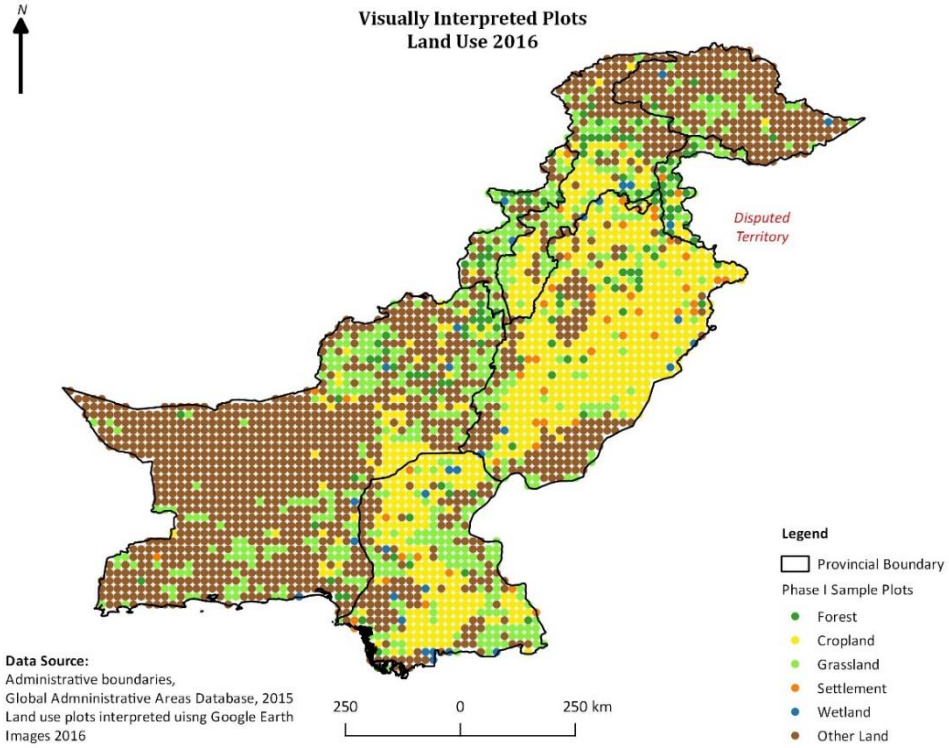


Figure 10 Phase I sample plots and land use categories

Land use assessment of plots shows general proportion of land use in the country (Table 11).

Table 11 Proportional Sample of Phase I plots (10') by land use.

Land Use	No. of Plots	Proportion of Plots (%)
Forest	128	4.33
Cropland	720	24.37
Grassland	558	18.89
Wetland	33	1.12
Settlement	51	1.73
Other Land	1,464	49.56
Total	**2,954**	**100 %**

Of the total plots, 4.33 % are forested plots, indicating approximate proportion of forest in the country. However, it should be noted that this is indicative and is refined/updated by wall-to-wall mapping using satellite images. In principle, sufficient sampling will yield similar proportions of the land use in comparing with the wall-to-wall mapping.

Land use assessment of plots shows general proportion of land use in the country. On the assessment of the land use categories of the Phase I plots for the provinces, estimation of the land use proportions for the year 2016 are shown (Table 12). Similarly, more accurate estimation of land use coverages is given by wall-to-wall mapping and error-adjustment using satellite imagery and more intense grid of visually assessed plots.

Table 12 Proportions of land use in provinces based on Phase I sampling (in %)

Land Use	GB	KP	FATA	AJK	PB	SD	BN
Forest	2.0	7.1	17.8	39.6	3.7	2.6	2.6
Cropland	0.4	26.9	3.3	12.5	57.5	37.3	5.4
Grassland	13.4	24.3	44.4	29.2	12.3	26.8	17.3
Wetland	0.8	1.1	2.2	2.1	1.0	2.6	0.5
Settlement		0.7	1.1	4.2	4.6	2.4	0.3
Other Land	83.3	39.9	31.1	12.5	21.0	28.3	73.9

2.5.2. *Sample Design*

Cluster sampling was designed because of several practical considers. Clusters are cost-efficient to measure since field plots are close to one another. Important point to note is spatial autocorrelation. Spatial autocorrelation means that field plots which are close to one another are more similar than plots which are far apart. The level of spatial autocorrelation has been tested and the distance between the plots within a cluster set are based on the pilot inventory data.

When applying the stratified two-phase sampling, the Phase II sample points were treated as the Primary Sample Units (PSU) for forest inventory. Secondary Sampling Units (SSU) are created using the PSU as the starting point. The SSUs can be in line, L-shape, square, triangle or cross formation or some combination of those. The number of plots in a cluster was set so that a field team can measure one cluster per day. The cluster design can also be combined with other sampling methods by replacing clusters with stratified simple random sampling when land uses are very scattered and fragmented.

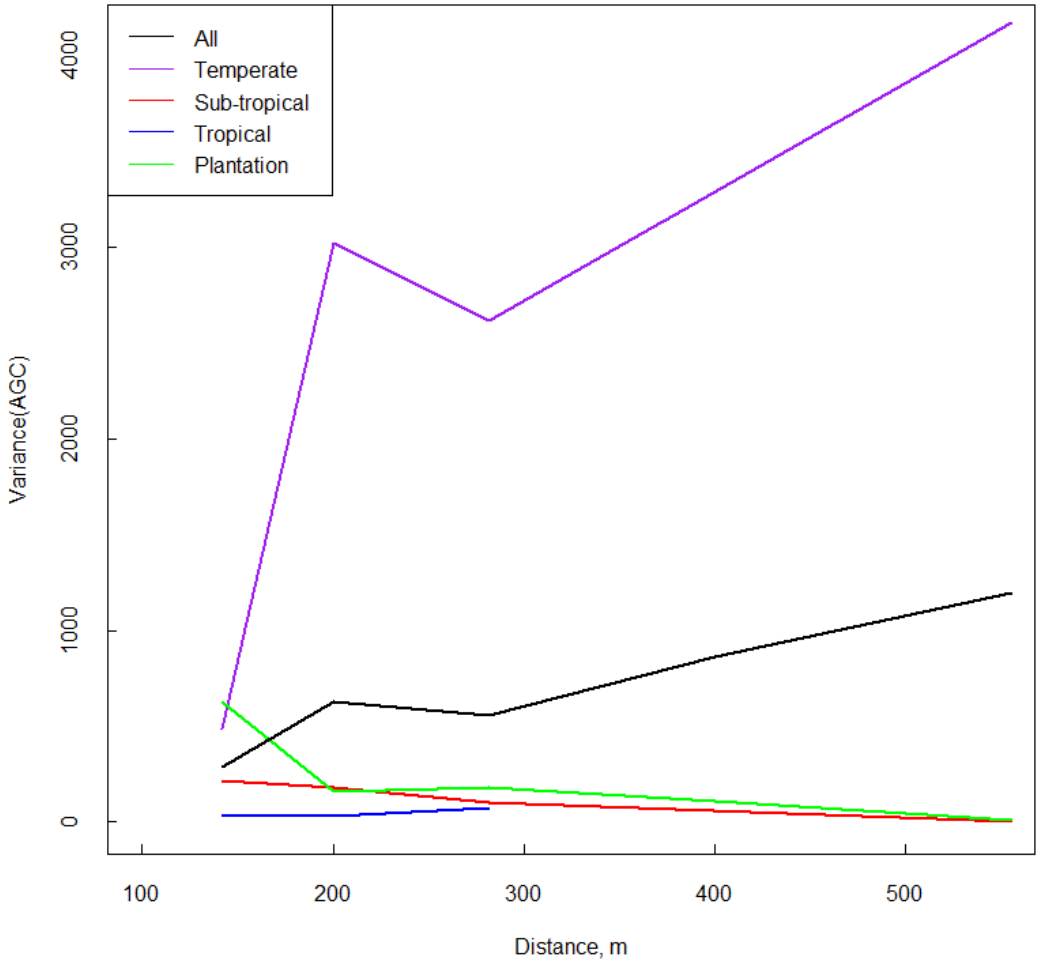


Figure 11 Above-ground carbon density semi-variogram as a function of the distance between neighboring sample plots over the different climate zones.

The plot design was decided in relation to the variation in the forest. The larger the sample plots are, the lower the between plot variation, and with lower between plot variation, number of sample plots required for certain precision level is decreased. The selected plot dimensions have been applied in Pakistan previously in KP and GB carbon inventories. It is based on the 17.84 meter (~1000 m^2) circular fixed radius nested plot (Figure 12). The plot design has two nested subplots, 5.64 meters radius (~100 m^2) and 0.56 meters radius (~1 m^2). The more time-consuming and difficult pools are measured from the inner subplots. The optimal distance between the plots was assessed using the semi-

variogram analysis to capture the maximum biomass variation using canopy cover as the proxy variable for above-ground biomass. The optimal distance was assessed to be 200 meters between the nearest squared cluster corner plots (Figure 13). After the pilot NFI inventory the same exercise was conducted with the measured biomass plots (Figure 11).

The complete forest inventory workflow is illustrated in Figure 14.

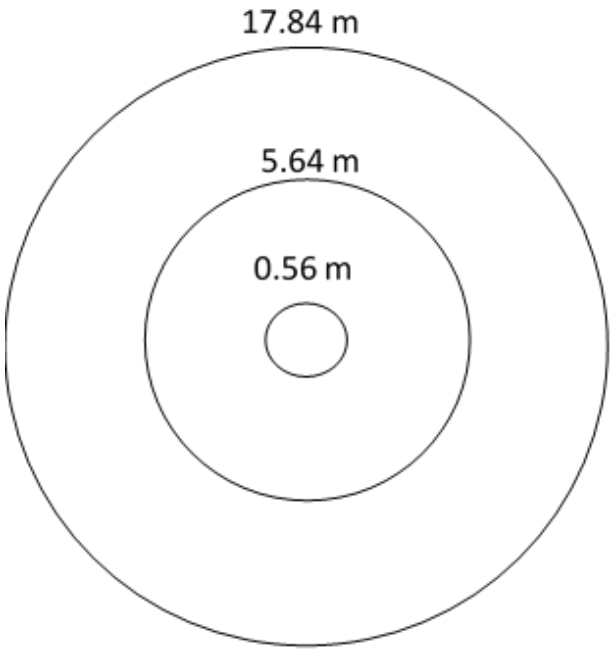


Figure 12 Field plot design of nested circular fixed radius plot

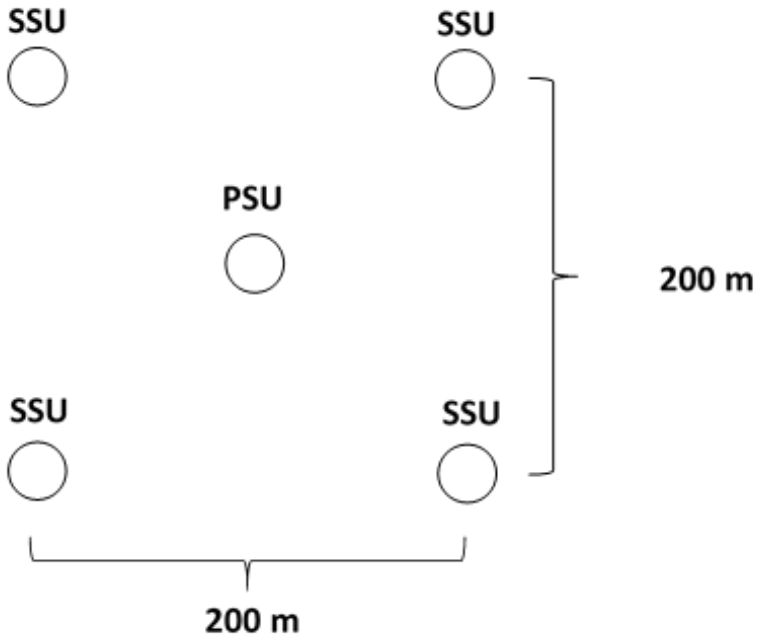


Figure 13 Cluster design with Primary Sampling Unit (PSU) and four Secondary Sampling Units (SSU) in square formation.

2.5.3. *National Forest Inventory protocol and quality assurance*

Due to logistical optimisation, one field team is recommended to be comprised of 3 core members. A team should have a team leader who takes responsibility of the equipment and that everything runs smoothly. Team leaders is also responsible of the data. Team should also comprise of botanist/ecologist or a team member with good knowledge of the tree species in the inventory region. One person should be responsible of the navigation and GNSS devices. A local forester or other local contact person is useful to get local information on the logistics, tree species, or for example navigation. Whenever other variables are included for measurement, team composition should be updated to take this into consideration. Team members are of course not confined into their respective duties only, but all tasks are shared evenly, and everyone should know the basics from all tasks to be able to help in any task when needed.

The aboveground and, belowground pools are included in the National Forest Inventory for the carbon stock assessment are the. Belowground pool is derived from the aboveground pool using the root-shoot ratio coefficients. This is because the belowground pool is the most difficult and time-consuming pools to directly measure, and there is strong relation between the above- and belowground biomass pools.

The most important aspect of inventory measurements is that the measurement rules are set beforehand, the rules are clearly explained in field manual and the rules are taught to the field teams in inventory training before starting measurement campaign. Proper field training is one key thing is to ensure that the quality will be on par to the requirements. This is necessary especially when the measurement practices introduce some new equipment. Also, it is important

to have rules for different problem situations, for example when breast height location on a tree trunk has a branch or some anomaly. However, if there will be some problems in the field which have not been covered in field training, the head of the forest inventory process should be contacted always immediately, if possible, or informed before heading to the following clusters. The field manual should be then updated to cover any new emerging situation.

Aboveground measurements are quality controlled by the other field teams. About 10 per cents of field plots should be remeasured for quality control purposes. The quality-controlled plots will be used to determine the variation between team and find any possible systematic measurement errors. When several field teams are doing field work at the same region, the field teams can quality control each other. If only one team is doing field work, a separate quality control team should go and remeasure the required number of plots. The quality control measurements are then compared at the office to the original measurements for any bias in measurements. If problems are discovered, field teams can be retrained to ensure that the rest of the field work will be on par. As part of the quality control, also the recorded data files should be quality controlled. This should be preferably done in near real time during the campaign. In case of any possible problems they can be rectified in the field.

The detailed NFI Protocol and field survey manual is attached separately in the National Forest Inventory and Field Surveying Manual Version 1.1. The manual also includes a specific protocol for measurements in mangrove forests.

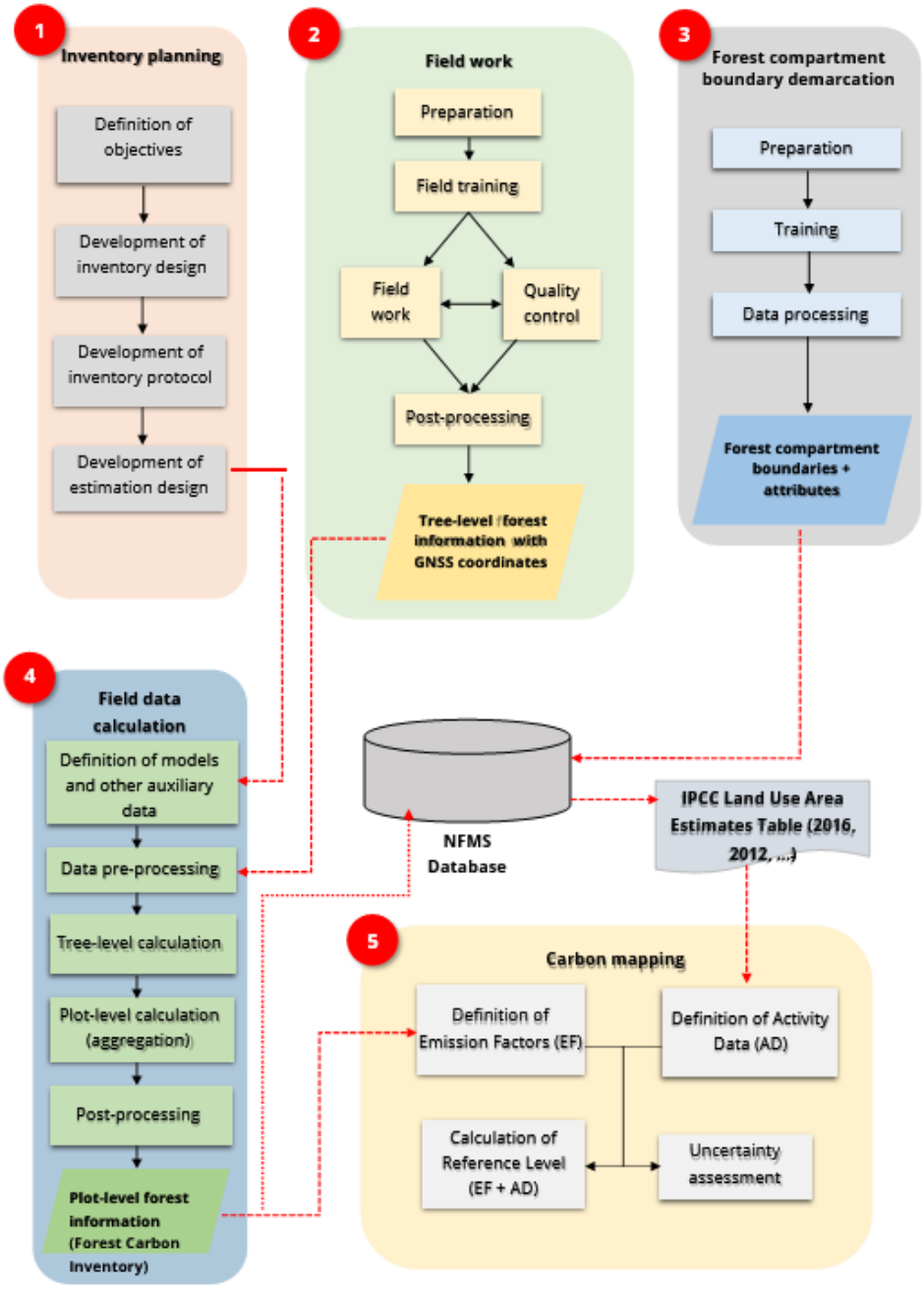


Figure 14 Workflow of the National Forest Inventory process and integration with NFMS database

2.5.4. *Data Storage and Processing*

Data entry. Both the tree-level field data and the GNSS coordinates are entered appropriately in the pre-designed field forms and tally sheets during the field work found in the manual. Alternatively, mobile devices such as tablets, mobile phones or field computers can be used instead of paper forms. Digital data is be sent directly to the data processing unit. In this way any quality issues could be caught during the field work and near-real time corrections could be made as needed. If paper tally sheets and forms are used, data entry should be done immediately after the field work, when everything is fresh in field team members' memory.

Plot position post-correction. The GNSS coordinates should be post-processed using a differential correction process in case the differential devices have been used. In differential correction, all the PSU and SSU center coordinates are corrected with base station data. A base station is located at a known location, either as a physical GNSS receiver station or a temporary station setup in proximity of the inventory area. The plot center positions are corrected based on a correction function created in the base station. In case handheld GNSS device units with relatively high accuracy of 2-5 m meters, averaging function needs to be used to ensure averaging of multiple position observations in the plot center.

Data cleansing. The tree-level data processing involves data checks and pre-processing for making sure that data does not contain any problems. In the case of NFI in Pakistan data processing and storage involves three steps:

Step 1 Data entry into worksheet/database system using worksheet or customized applications. data is entered using customized application developed on OpenForis Collect[1] (Figure 15).

Step 2 Validation of entered data for consistency and accuracy

Step 3 Uploading of validated data into NFMS National Forest Inventory Database

Data export. Data is converted to or exported in the CSV format which is suitable for the spreadsheet software used for inventory calculation

[1] http://www.openforis.org/tools/collect.html

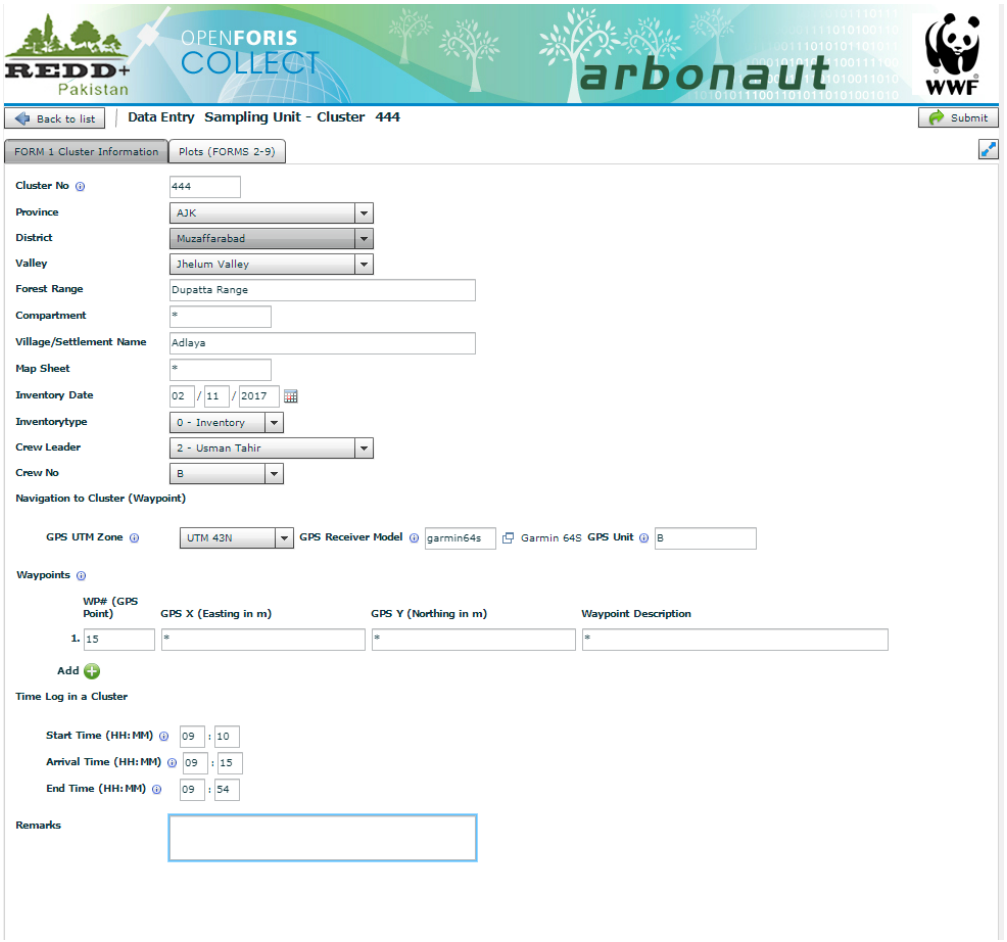


Figure 15 Screen capture of customized OpenForis Collect data entry tool.

Height diameter model development. The first inventory calculation step is to develop height-diameter (H-D) models. Once the heights have been measured only from sample trees, the H-D models are used to calculate height for all trees. H-D models are usually developed per species or per species-groups. The models are usually made using non-linear regression, like Näslund or power function. Also, many advanced methods can be included like mixed modelling (Mehtätalo et al. 2015). The best models should be selected always after testing different models with the data. For example, in case of the NFI pilot, 19 models are development covering the major species and species groups and the plot-specific regression coefficients are derived. The quality of the models is measured using descriptive variables for mean error (RMSE and relative RMSE) and (Bias, relative Bias and Bias p-value) as illustrated in Table 13.

Table 13 The Diameter-Height model descriptive statistics.

D-H Model Species	RMSE	RMSE %	Bias	Bias %	Bias p-value
Pinus wallichiana	4.75	0.23	0.00	0.00	0.99
Juniperus excelsa	1.07	0.21	-0.08	-0.02	0.36
Quercus incana	3.25	0.32	0.03	0.00	0.95
Eucalyptus	2.13	0.21	-0.12	-0.01	0.38
Acacia	1.73	0.27	-0.16	-0.03	0.12
Mangrove (Avicennia marina, Rhizophora mucronata, Ceriops tagal)	1.01	0.29	-0.02	0.00	0.80
Dalbergia sissoo	1.63	0.18	-0.03	0.00	0.88
Pinus gerardiana	1.73	0.21	-0.08	-0.01	0.77
Capparis decidua	1.84	0.30	-0.04	-0.01	0.93
Salvadora oleoides	1.15	0.28	-0.01	0.00	0.96
Tamarix aphylla	1.60	0.21	0.02	0.00	0.85
Monotheca buxifolia	1.20	0.30	-0.03	-0.01	0.87
Olea ferruginea	1.35	0.25	-0.03	-0.01	0.78
Abies pindrow	5.51	0.33	-0.36	-0.02	0.54
Prosopis cineraria & Prosopsis juliflora	1.13	0.15	-0.01	0.00	0.90
Cedrus deodara	1.03	0.05	-0.03	0.00	0.92
Pinus roxburghii	2.19	0.13	-0.23	-0.01	0.41
Conifer	3.53	0.25	-0.06	0.00	0.70
Deciduous	1.95	0.27	-0.14	-0.02	0.01

Allometric modelling. The other important set of models are the allometric models when estimating volume or biomass of the individual trees. Most important aspects of the allometric models is that the selected models are applicable for the geographical region and the trees in question. Moreover, it is important that the data and the measurement practices are applicable with the model. Usually the biomass models require measured diameter at breast height, tree height and/or wood density as the model explanatory variables. The available allometric equations recommended for the NFI calculation are found in Table 14.

Table 14 The identified equations for the tree-level aboveground biomass / carbon stock calculation. D refers to diameter at breast height, H to height and ρ to wood density.

Species scientific name	Vernacular name	Allometric equation	Reference
Cedrus deodara	Deodar	$AGB = 0.1779(D^2H)^{0.8103}$	Ali 2015
Pinus wallichiana	Kail	$AGB = 0.0631(D^2H)^{0.8798}$	Ali 2015
Pinus gerardiana	Chilghoza	$AGB = 0.0253D^{2.6077}$	Ali 2015
Abies pindrow	Fir	$AGB = 0.0954(D^2H)^{0.8114}$	Ali 2015
Picea smithiana	Spruce	$AGB = 0.0843(D^2H)^{0.8472}$	Ali 2015
Avicennia marina	White mangrove (Timar)	$AGB = 0.827D + 0.275$	Prasanna et al 2017
Rhizophora mucronata	Kamo	$AGB = 0.8069D^{2.5154}$	Kirui et al 2006
General	Coniferous species	$AGB = 0.1645(\rho D^2H)^{0.8586}$	Ali 2015
General	All species	$AGB = 0.112(\rho D^2H)^{0.976}$	Chave et al 2014

Plot level and stratified aggregation. The data calculation should result to aggregated plot-level aboveground biomass and carbon results with the post-processed GNSS coordinates. The above-ground biomass density is calculated using the sample plot data to represent biomass density per hectare (ha). The belowground biomass for a plot is calculated using the default IPCC root-shoot ratios (Table 15). The default IPCC fraction (0.47) is applied to convert biomass to carbon. The plot level averages can be then used to develop average carbon

contents per forest and land use classes. The pilot NFI inventory results by forest types are found in Annex 3.

Table 15 The applied IPCC root-shoot ratios adapted from Table 4.4[1] of the IPCC Good Practice Guidance (2006).

Domain	Vegetation type	Aboveground biomass (t/ha)	Mean value (BGB:AGB)
Tropical/Sub-tropical Forest (Dry)	Riverine forest	>20	0.28
	Riverine forest	<20	0.56
	Mangroves[2]	NA	0.29
	Eucalypt plantation	<50	0.44
	Eucalypt plantation	50-150	0.28
	Eucalypt plantation	>150	0.20
Sub-tropical & Temperate Forest	Conifers	<50	0.40
	Conifers	50-150	0.29
	Conifers	>150	0.20
Temperate Forest	Oak forest	>70	0.30
	Other broadleaf forest	<75	0.46
	Other broadleaf forest	75-150	0.23
	Other broadleaf forest	>150	0.24

Emission/removal factor development. Emission and removal factors are combined with the activity data to create FREL/FRL over a historical period. The emission and removal factors are developed according to the stock-difference approach described in the IPCC Guidelines (2006). The factors represent emissions and removals per ha of land, which is either remaining as forest, has been converted to non-forest or to forest.

2.6. Methodological Framework of GHG-I

The National Communications and Biennial Update Report submissions shall be prepared in accordance with the guidelines contained in UNFCCC COP decision 2/CP.17. A national GHG inventory is a key element of the national communication. A greenhouse gas inventory is a comprehensive listing of annual GHG emissions and removals resulting directly from human activities by sources. An inventory estimates emissions and removals for one year or several years. For the Non-Annex countries, the Initial National Communication inventory for 1994 and National Communication inventory for 2000 are

[1]https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf
[2] https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_separate_files/WS_Chp4_Coastal_Wetlands.pdf

suggested, but they are also welcomed to report other years. It is mandatory to report CO_2, CH_4 and N_2O, while are they encouraged to report other gases according to their capacities.

The IPCC inventory guidance (IPCC 1997, 2000 and 2003) applicable to non-Annex I Parties refers to six inventory sectors: Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land Use, Land-Use Change and Forestry (LULUCF); and Waste. Within these sectors, individual source and sinks categories are defined. Updated guidance for the development of national GHG inventories is provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC 2006 refers to five inventory categories including energy; industrial processes and products; agriculture, forestry and other land use; waste and other. Parties to the UNFCCC are required to report their inventories in line with the definitions and structure of these sectors, and the source and sink categories within each sector, so that reporting is comparable across Parties.

The GHG-I reports contain the following contents:

• Tables of annual emission and removal estimates by source, with estimates expressed in units of mass per year, and the year or years;

• Worksheets showing how emissions are calculated, including all parameters used for calculations;

• For each source, a description of the methodology, the sources of data (e.g. activity data, emission factors, methodologies), the actual data and a description of uncertainties, and quantitative assessment of uncertainties (if possible); and

• Other informative background data (e.g. a national energy balance, a description of GHG sources that are believed to be important but cannot be estimated).

The GHG-I processes must be transparent, consistent, comparable, complete and accurate in the context of the UNFCCC reporting:

Transparency means that the assumptions and methodologies used for an inventory are clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental for the success of the process for the communication and consideration of information;
Consistency means that an inventory is internally consistent in all its elements with inventories of other years. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks. Under some circumstances, an inventory using different methodologies for different years can be consistent if it has been recalculated in a transparent manner, in accordance with the IPCC good practice guidance;
Comparability means that estimates of emissions and removals reported by COP Parties in their inventories are comparable;
Completeness means that an inventory covers all sources and sinks, as well as all gases, included in the IPCC Guidelines, as well as other existing relevant source/sink categories which are specific to individual Parties and, therefore,

may not be included in the IPCC Guidelines. Completeness also means full geographic coverage of sources and sinks of a Party;
Accuracy is a relative measure of the exactness of an emission or removal estimate. Estimates should be accurate in the sense that they are systematically neither over nor under true emissions or removals, as far as can be judged, and that uncertainties are reduced as far as practicable.

NFMS provides all the relevant information for the national GHG-I for forestland remaining forest land, forestland converted to other land use or other land use is converted to forestland. All Forest Land in Pakistan is considered as Managed Land. 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry and Other Land Use) are to be applied as the methodological reference to ensure consistency with the FREL/FRL developed for 1996-2016. The activity data is sourced from SLMS and the emission/removal factors from NFI. The customised GHG-I training manual is available as attachment to complement IPCC Inventory Software (version 2.54.6396.19217) User Manual Version 2.17.

2.7. Methodological Framework for MBIGS

NFMS may integrate data and information that is relevant for other components of the REDD+ information system, such as the Safeguards Information System (SIS) (UNFCCC Decision 1/CP.16, Para 71 d). The following safeguards should be promoted and supported when implementing REDD+ activities (UNFCCC 1/CP.16, Appendix):

- That actions complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements;
- Transparent and effective national forest governance structures, taking into account national legislation and sovereignty;
- Respect for the knowledge and rights of indigenous peoples and members of local communities, by taking into account relevant international obligations, national circumstances and laws, and noting that the United Nations General Assembly has adopted the United Nations Declaration on the Rights of Indigenous Peoples;
- The full and effective participation of relevant stakeholders, in particular indigenous peoples and local communities, in the actions referred to in paragraphs 70 and 72
- That actions are consistent with the conservation of natural forests and biological diversity, ensuring that the actions referred to in paragraph 70 of this decision are not used for the conversion of natural forests, but are instead used to incentivize the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits, taking into account the need for sustainable livelihoods of indigenous peoples and local communities and their interdependence on forests in most countries, reflected in the United Nations Declaration on the Rights of Indigenous Peoples, as well as the International Mother Earth Day.
- Actions to address the risks of reversals;

- Actions to reduce displacement of emissions.

SIS provides a systematic approach for collecting and providing information on how REDD+ safeguards are being addressed and respected throughout REDD+ implementation. The information is to be submitted periodically in national communications to the UNFCCC. SIS is expected to be simple, accessible, inclusive, transparent, auditable, comprehensive and according to national legislation. The first step of the process has been interpreting the Cancun safeguards to be addressed and respected in the context of Pakistan. In the second stage the institutional arrangements have been outlined. Thirdly, the reporting templates containing qualitative and quantitative indicator contents have been defined.

Pakistan's R-PP (2013) provides a reference to the monitoring needs of Multiple Benefits, Impacts, Governance and Safeguards (MBIGS) of the REDD+ programme implementation as a NFMS function. The tentative list of common MBIGS to be monitored is provided in R-PP (2013). Some forest-type specific MBIGS are to be reported for the REDD+ implementation environments such as silvo-pastoral impacts on forested rangeland, coastal zone protection in mangroves, eco-tourism development in national parks. The MBIGS design has been harmonised with the NFMS data model (Figure 17) and SIS development processes (Climate Law and Policy/Hagler Bailly Pakistan, 2018b) with guidance from the REDD+ Thematic Working Groups. The harmonised MBIGS/SIS indicators to be collected by REDD+ intervention areas and provinces are found in Table 16.

Table 16. Recommended MBIGS indicators to be collected by REDD+ intervention areas and provinces and labelled by sources.

Multiple Benefits	**Indicators**
Sustainable extraction of NTFPs by local communities for subsistence use and small-scale local enterprises	1. Description of non-timber forest products extracted 2. Volume of extracted non-timber products
Increased production of timber in natural forests, potential for lifting or easing of timber ban	3. Production of timber from natural forests by species 4. Growing stock in natural forests by species
Increased production of timber from plantations	5. Production of timber from plantations by species 6. Growing stock in natural forests by species
Changes in natural values, biodiversity, wildlife, potential for eco-tourism	7. General description of activities (and where possible, outcomes) relating to: the identification/valuation of ecosystem services, payment for ecosystem services, alternative livelihood/rural development, eco-tourism. 8. Total number of species (plants/wildlife) 9. Proportion of the native tree species of the total tree basal area 10. Amounts disbursed from PES schemes
Desertification control, erosion control, watershed protection, quantity and quality of streams	11. Deserted/eroded area 12. Vulnerable area for hazards 13. Number and area of fires
Impacts	
Socio-economic impacts from participation in forest management, changing forest resource utilization patterns, availability of raw materials for processing	1. Forest related jobs or businesses created 2. Improvement in household income 3. Change in women's disposable income
Resource impacts, including forest development, desertification control, erosion control, watershed protection	4. General description of how natural/untouched forests and biological diversity has been recognised and protected during REDD+ implementation (EIAs developed/implemented), environmental assessment framework followed.

	5. Confirmation that no natural/untouched forests have been converted as a result of REDD+ implementation. 6. Natural/untouched forest area before/after REDD+ implementation 7. Number of project proposals granted/refused authorization (percentage) 8. Number of EIAs completed/implemented per province (percentage)
Impact of distribution of benefits on local socio-economic conditions	9. Improved access to social services (health, education, training, credit) 10. Improvement in access to services (education, training, health, credit) in collectively owned/managed forests 11. Improvement in women's access to services (health, education, training, credit)
Governance	
Forest policies, including land tenure, rights to forest resources, carbon rights and policy reform	1. General description of the efforts made to recognise, document and enforce forest and land tenure claims including customary claims. 2. General description of the efforts made in respecting the rights of native communities and tribal communities in REDD+ 3. Number of registered rights-holders (before/after implementation) 4. Number of unregistered rights-holders areas (before/after implementation) 5. Number of tenure related disputes (before/after implementation) 6. Number of resettlements (after implementation) 7. Number of people from tribal populations present 8. Number of collectively owned/managed forests (before/after implementation) 9. Number of contested collectively owned/managed forests (before/after implementation)
Law enforcement	10. Number of encroachers 11. Number of encroachment cases registered at police 12. Number of civil suitcases for encroachment

Transparency and anti-corruption	13. General description of information sharing/dissemination activities undertaken in relation to each strategic option 14. Number of awareness-raising workshops held and number of attendees 15. Number of requests for information received and number dealt with (percentage rejected and granted) in each province 16. Number of appeals lodged in each province 17. Average time for dealing with requests/appeals in each province 18. Description of procurement processes (consultants, companies) involved in the implementation of each strategy option 19. Description of procurement outcomes 20. Evidence of how REDD+ finance has been spent (per strategic option based on audited reports) 21. Number of corruption-related denunciations lodged/number investigated/prosecuted (percentage)
Management of the National REDD+ Program, inclusion of stakeholders in consultation and review	22. General description of the efforts made to carry out consultations and involve local people in the REDD+ design and implemenation process (awareness-raising, types of consultations held) 23. Number of meetings held, number of participants per meeting, categories of participant 24. Number of views gathered (feedback forms, interviews, votes, minutes recorded and disseminated), per REDD+ intervention area 25. General description of the efforts made in identifying and respecting traditional knowledge in REDD+ in Pakistan 26. Number of sacred groves/areas in REDD+ intervention areas (before/after implementation), per province 27. Evidence of traditional knowledge/practices recognized/integrated into REDD+ implementation (intellectual property, traditional practice protocol) 28. General description of any additional measures taken to engage native communities, tribal population and vulnerable

	groups in REDD+ planning and implementation (culturally appropriate communications and outreach). 29. Description of FPIC processes followed where appropriate 30. Number of participants from native communities, tribal population and vulnerable groups engaged in consultations (percentage) 31. Number of FPIC processes carried out 32. Proportion of women involved in REDD+ planning/implementation 33. Emission projections 34. Emission reductions 35. General description on the types of measures to identify and address risks of reversals 36. Rates of reversals of emissions 37. General description on the types of measures to identify and address risks of leakage of emissions 38. Rates of deforestation in neighbouring areas before and after the REDD+ intervention implementation
Benefit distribution policies	39. Description of how benefits from REDD+ (monetary and non monetary) are shared (with local populations) 40. Description of the efforts made to meaningfully involve women to share in the benefits (monetary and non-monetary). 41. Total finance disbursed 42. Total finance disbursed collectively to community owned/managed forests 43. Proportion of woment receiving monetary/non-monetary benefits from REDD+
Conflict resolution mechanisms	44. General description of the types of grievances received in relation to REDD+ by the FRGM and other relevant entities and how they were dealt with 45. Number of grievances received 46. Number of grievances investigated 47. Number of grievances resulting in the establishment of a mediation assembly 48. Number of grievances apealed to the courts/unresolved (percentage)

At the beginning there must be developed a REDD+ project baseline for each MBIGS variable. The NFMS system provides quantitative information regarding to the natural/untouched forest, species diversity information and deforestation figures in neighbouring areas can be retrieved from forest maps combined with dedicated forest management and biodiversity inventory surveys. The emission projections are derived following the FREL/FRL development processes and reduced emissions are detected with MRV.

The socio-economic baseline can draw on the existing national and provincial monitoring programs (e.g. demographic and social surveys), and leverage both secondary and primary datasets. For socio-economic monitoring at the REDD+ project level, more expensive primary data collection would include extensive household surveys, whereas a less expensive approach is based on the participatory methods at the community level. Methodology to be used for the monitoring process of indicators includes interviews, questionnaires, direct observation and public consultations whenever necessary.

2.8. Methodological Framework for NFMS Web Portal and data repository

The NFMS web portal serves as an integrated platform for transparent sharing and access of data to all the participating REDD+ stakeholders and general public.

Steps	Process	Outcome/Design Decisions
Step 1	Assessment of available data, data gaps and potential users	▪ Identification of data requirements and potential users
Step 2	Assessment of Institutional Capacities and Identification of Potential Institutions (for data ownership, custodianship, system hosting, admin service provider)	▪ Institutions/organizations capable of hosting and administering the NFMS system
Step 3	System Needs Assessment	▪ Key informants' consultation for Users' Requirement Assessment for NFMS (Oct – Dec 2017)
Step 4	System Design and Prototype	▪ NFMS System Prototype
Step 5	Directives for GCISC by MOCC for hosting of NFMS Web Portal	▪ National REDD+ Steering Committee Meeting held on 9th April 2018 that decided GCISC as the national organization to host the NFMS
Step 6	Assessment of available system hardware and	▪ Initial meeting is conducted on for specifications.

	infrastructure at GCISC	▪ The server specifications are evaluated ▪ The minimum specifications to run NFMS provided
Step 7	Development of Data Policy, Sharing Protocol and Modality (Terms and Conditions)	▪ Generally open data policy as per new approved Digital Policy except few sensitive information. ▪ Standard data sharing protocol form is designed with authorized signatures etc. ▪ Data Ownership, Custodianship, Policy and Sharing Document
Step 8	NFMS Web Portal Deployment and Testing	▪ Deployment in GCISC ▪ GeoNode Platform on Linux Platform (Choice between CentOS and Ubuntu) ▪ Use of open source technologies ▪ See attachment (NFMS Web Portal Deployment and Testing Document)
Step 9	Testing	▪ Functional testing ▪ Performance testing ▪ Compatibility testing ▪ Security testing ▪ Usability testing
Step 10	Capacity Building	▪ As part of O & M (minimum six months after hand over) ▪ Various Trainings
Step 11	Development of Institutionalization and Sustainability Action Plan	▪ Establishment of the technical units ▪ Setting up of participatory process ▪ Clarification of mandates within the technical units ▪ Promulgation of institutional arrangements
Step 12	Transferring of System and Knowledge to MOCC (to GCISC and stakeholders)	▪ As part of O & M (minimum six months after hand over) ▪ Training on system administration ▪ Training on NFMS technologies including GeoNode etc. ▪ Creating dedicated technical (developers) and system

		administrator positions in the department ▪ Running awareness programs

2.8.1. *System Architecture*

The NFMS Web application contains different server parts built on top of Free and Open Source Software (FOSS) (including GeoServer, database, proxy, map server), open source map handling applications and libraries. The servers are to be placed in a specified and enough secured place. The server maintenance and upgrade processes need to be defined within data update process. The server system management may be handled through VPN/SSL secured connection. Database data backups need to be taken automatically within regular time periods into a certain store.

Open source map handling is using OpenLayers library, which makes it easy to setup dynamic map in the web page. It can display map tiles, vector data and points loaded from the dedicated database. OpenLayers has been developed to further the use of geographic information. The reporting part may handle the pre-defined report forms. and report export format.

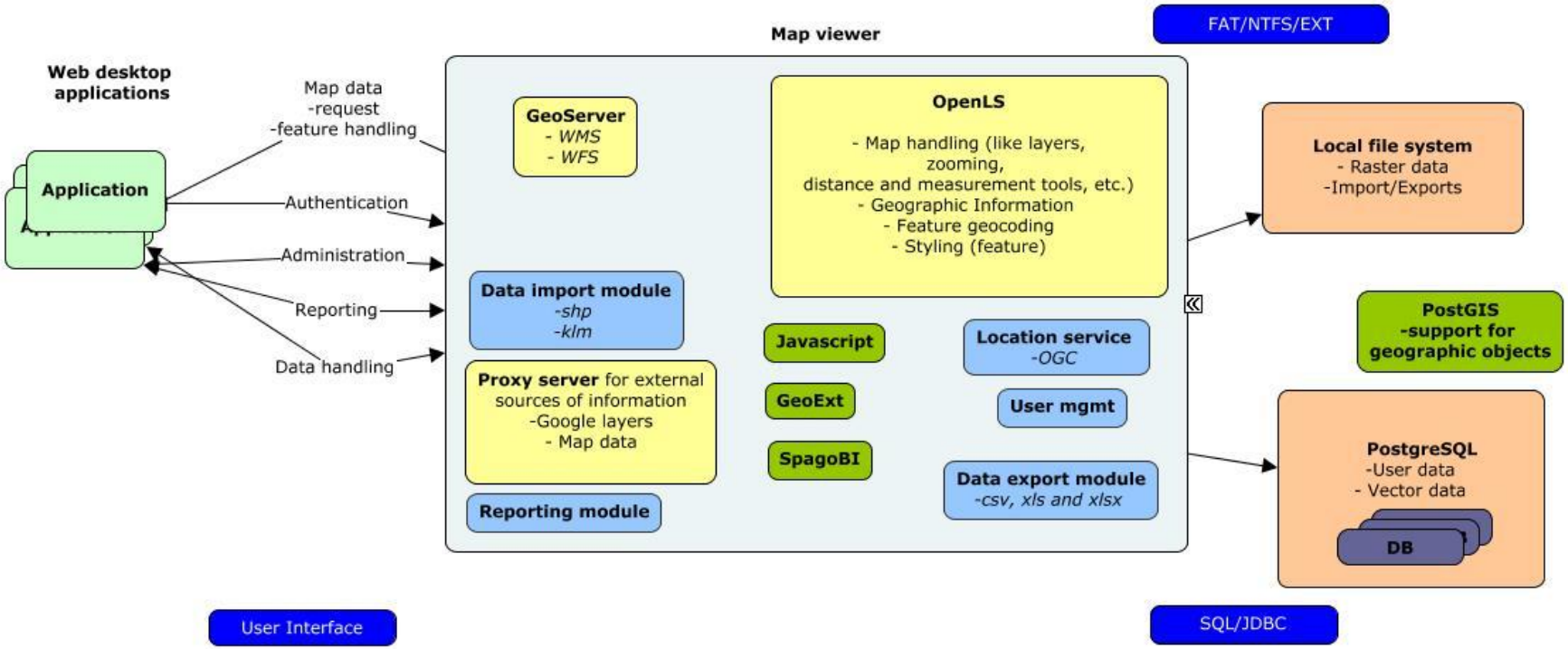


Figure 16 NFMS System Architecture.

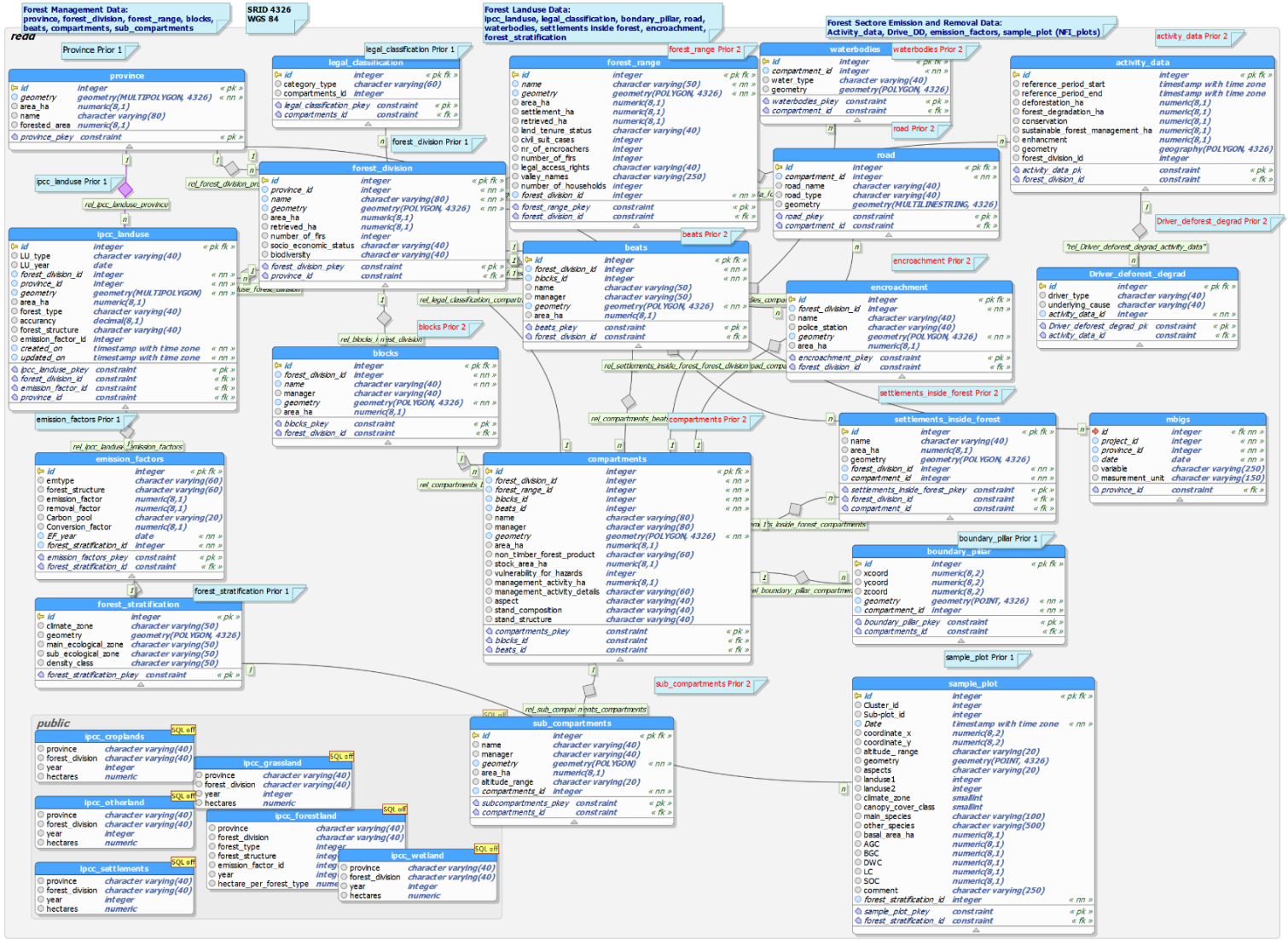


Figure 17 NFMS data model.

2.8.2. *System Components*

The NFMS platform is developed on top of the open source geospatial content management system platform GeoNode[1] containing GeoServer as a map server, PostgreSQL/PostGIS as spatial database backend, Geotools as java libraries to provide GIS functionalities and other components (Figure 18 and Figure 19)

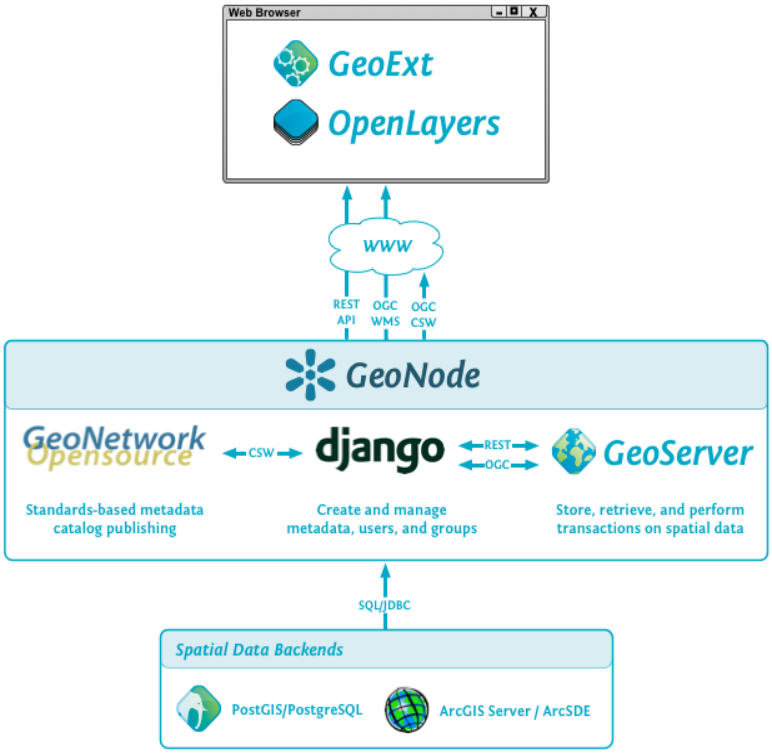


Figure 18 GeoNode high level architecture.

[1] http://geonode.org/

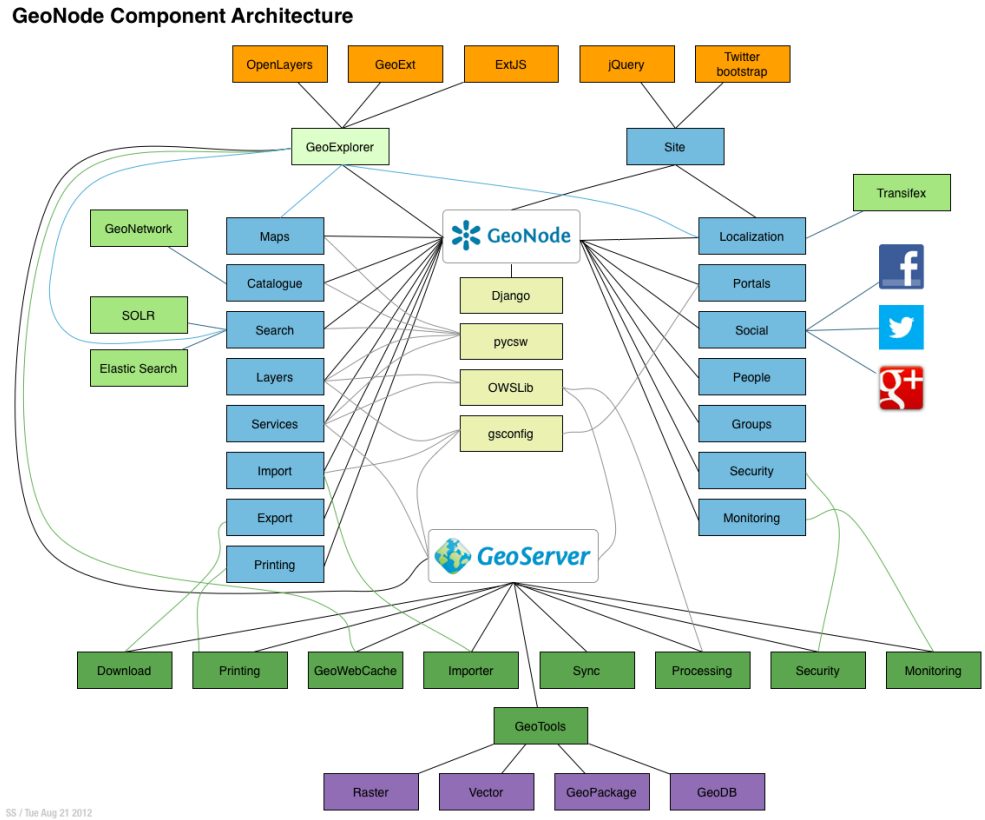


Figure 19 GeoNode Component architecture.

The NFMS GeoNode system architecture contains the following components:

Django

Django[1] is a Python based web framework on top of which GeoNode has been developed. The main objective of Django is to facilitate the creation of complex sites-oriented databases. Django emphasizes reusability, rapid development and is used for configurations settings, files, and data models.

PostgreSQL/PostGIS

PostgreSQL is an open source object-relational database system. PostgreSQL is known for its proven reliability, feature robustness, and performance. In PostgreSQL one can define its own data types and build custom functions. PostgreSQL PostGIS extension is the backbone of GeoNode and stores all spatial data. PostGIS is described in next Section while details can be viewed at: https://www.postgresql.org/

PostGIS is a spatial extension of the PostgreSQL database management system. This is a well-known open source project for

[1] https://www.djangoproject.com/

storing and querying geographical entities. PostGIS is fully compliant with OGC standards such as Simple Feature Specifications (SFS) for SQL. PostGIS is the main spatial database supported by GeoNode. The details can be viewed at: https://postgis.net/

GeoTools

GeoTools[1] is an open source Java library that provides advanced GIS functionalities. It supports vector and raster geospatial data formats, DBMS access and rendering of complex maps. Being one of the oldest projects of Open Geospatial Foundation, it is fully compliant with OGC specifications including GML, WMS, WFS, grid coverage, coordinate transformation and SLD. GeoTools is one of the power libraries used in GeoNode.

GeoServer

GeoServer[2] is a popular open source GIS project. It has a web administration tool to configure its spatial and non-spatial options. Apart from WMS, WCS and WFS, it additionally supports the editing of feature services on the client side using WFS-transactional. GeoServer is built on Java technology and runs on an integrated Jetty web server. It heavily relies on GeoTools already covered. All the GeoNode data is published through GeoServer.

GeoWebCache

GeoWebCache[3] is a Java web application used to cache map tiles coming from a variety of sources such as WMS. It implements other standards including WMS-C, WMTS, TMS, Google Maps KML and Virtual Earth in order to accelerate and optimize map image delivery. It can also recombine tiles to work with regular WMS clients. GeoWebCache is an integral part of GeoNode.

Mapfish Printing Module

MapFish Print[4] allows printing maps as PDFs. This is written in Java. It is typically executed as a servlet in a servlet container for example, Apache Tomcat. MapFish Print is released under the GPLv3 license.

OpenLayers

OpenLayers[5] is a JavaScript library for displaying spatial data in web browsers, without server-side dependencies. OpenLayers implements a JavaScript API for building rich web-based geographic applications, constituting the main open source alternative to the equivalent commercial tools. As with many open source geospatial technologies,

[1] http://www.geotools.org/
[2] http://geoserver.org/
[3] http://geowebcache.org/
[4] http://www.mapfish.org
[5] https://openlayers.org

OpenLayers implements industry-standard methods for geographic data access, such as the WMS and WFS.

GeoExt

GeoExt[1] is a combination of OpenLayers (discussed above) and Ext JS. Ext JS is a cross-browser JavaScript library for building web interfaces. It includes a set of user interface widgets, an extensible component model and an API. The Ext JS library and its related products have experienced success recently, becoming ubiquitous in complex web applications. The library is currently used by several major international corporations for intranet and internet websites. Ext JS can work as a standalone library and can integrate with the Prototype Javascript library. The work has been extended by a project called GeoExt which embeds OpenLayers with Ext JS to provide a framework to build desktop-like web GIS applications.

There are additional components which help build GeoNode together are as follows:

- GXP
- gsconfig.py
- owslib
- django-registration
- django-avatar
- South

Following tools are used to build GeoNode:

- Paver
- Maven
- Git
- Bash

2.8.3. *User interface*

User will be authenticated during the login into system (Figure 20). This will check the user role and his/her feature permissions for the different views or modifications. User could update the data or just viewing some of them according his/her permissions (Figure 21).

[1] http://geoext.org/

Expert or system owner can administrate the system at back-end to update data and define statistics through a web GUI (version control management rights). User can share maps and reports.

Expert or system owner can fetch forest information by compartment level, or by any geographical boundaries up to provincial and national level. User can aggregate statistics and generate charts using an XML document as statistic definition. User can compare sub-national results to national. User can compare past results to new.

Expert and generic user may view time series datasets. User can scroll LULUCF maps and background satellite imagery in a timeline to produce situational picture of wanted point in time.

System is built to be open for storing LU maps for subsequent time points (underlying remote sensing data stored externally).

2.8.4. *Information contents*

The following information contents is defined for the web-portal data repository:

- Standard methodology for FREL/ FRL development including uncertainty assessment
- Forest definition
- Definition for significant pools and GHGs
- Sub-categories/ classes of the IPCC recommended six land cover categories
- Definition of reference period
- Emission factors
- Forest compartment boundaries
- Admin boundaries (national and sub-national)
- Biophysical boundaries (ecological zones)
- REDD+ project area boundaries
- Forest owner boundaries
- NFI plot-level data
- Land use and cover maps
- Activity data maps
- Spatial deforestation, degradation and carbon stock enhancement maps & statistics by provinces
- MBIGS data for the REDD+ implementation areas
- A link to the carbon registry interface for the registered projects and claimed and attributed emission reduction units.

2.8.5. *User management (permission)*

User management roles:

a. Superuser (if needed)

- Giving access rights to admin (handle admin accounts) (at MOCC/NCCA[1])

b. Expert (1 in MOCC and 1 appointed at time from each province/territory, total 1+7)

- Uploading the map layer data
- Editing feature attributes
- May modify defined features
- Styling features
- Data access handling
- User accounts (creating user, activate/deactivate accounts)
- Creating reports

c. Normal user

- Viewing, adding own features
- Modifying own feature attributes
- Seeing his/her own reports

d. Guest

- Limited content view / limited data access / no modification access

2.8.6. *Uploading and updating interface*

a. Vectors (in DB) and rasters (in Geoserver) map layer data maintaining by Admin. Loading vector data (.shp ESRI format files) through data import module
b. Loading measured, updated data via .CSV or .XLS data into database

- WMS interface (may tiled in Geoserver)
- WFS interface (feature attributes)

c. Items (like points and areas) with geometries are stored in database

[1] The functions of the NRO will be taken over by the Pakistan Climate Change Authority established under Section 5 of the Climate Change Act, 2017.

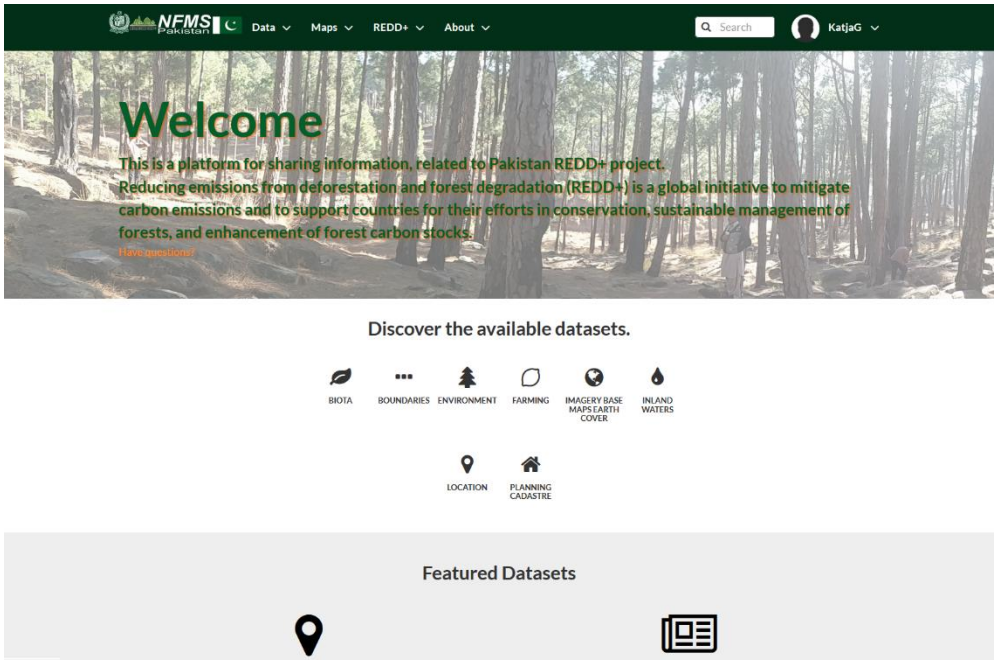
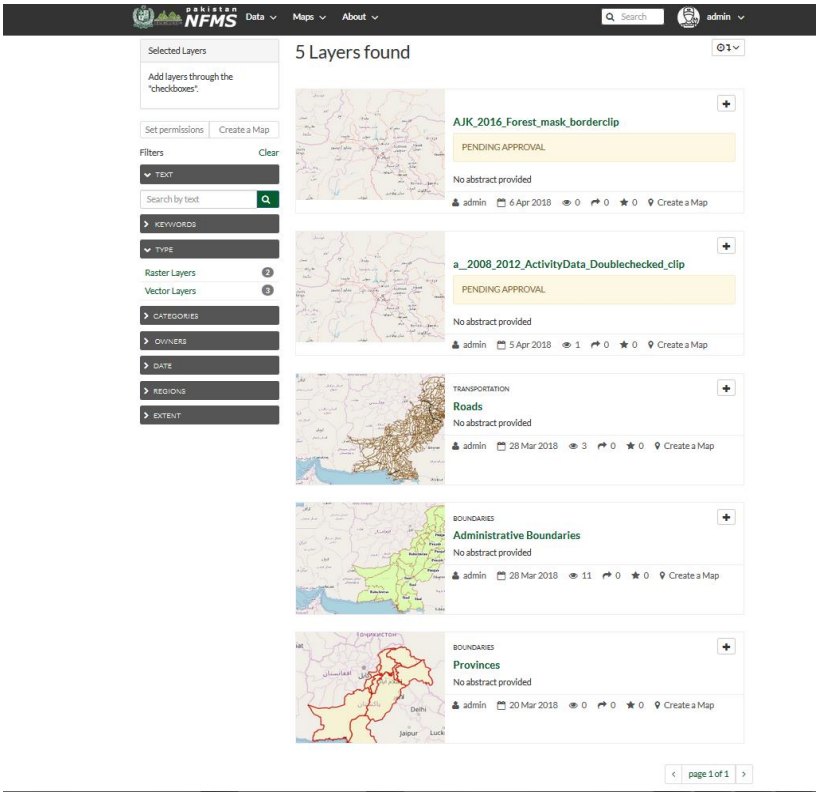


Figure 20 NFMS web application interface



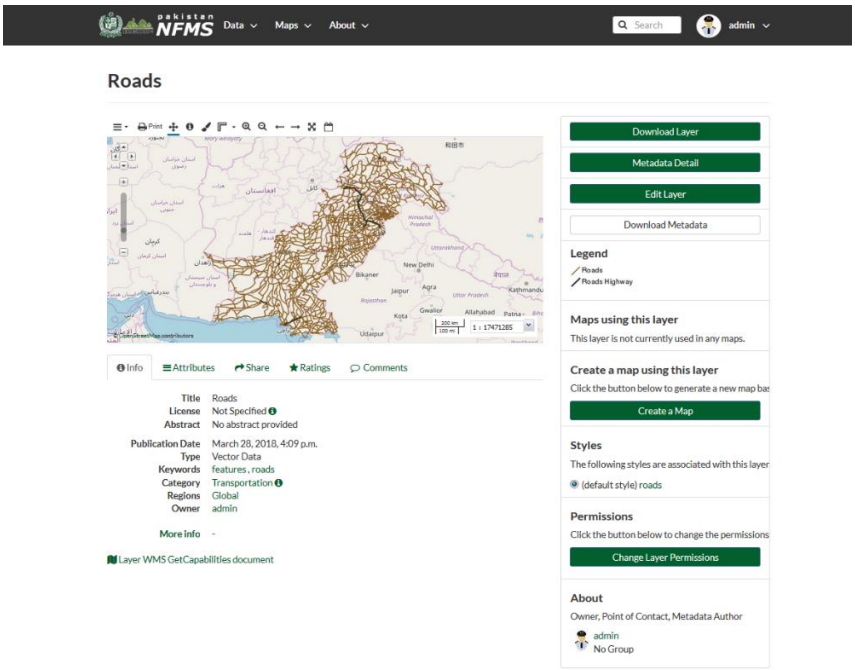


Figure 21 Spatial layer search and metadata interface

3. OPERATION AND INSTITUTIONALIZATION OF NFMS

3.1. Data Ownership, Custodianship and Sharing Agreement

There are the following considerations as per scope of NFMS:

i. Primary NFMS data ownership will be retained by the Provincial Governments. MOCC will be the custodian through GCISC (until NCCA[1] is established in MOCC). The Provincial REDD+ Units are provided with the mandate to collect, manage and disseminate the NFMS data pertinent to their own provincial territories.
ii. GCISC is a dedicated research institute for climate change studies in Pakistan. GCISC is having physical infrastructure to host NFMS with the National Steering Committee Meeting decision taken in April 2018. A data centre within MOCC is recommended to be established to manage NFMS data and to further regulate data dissemination.
iii. GCISC must establish a data division with a dedicated officer who is the first point of contact in case of any data related queries in coordination with the provincial REDD+ units. There are subsequent levels up in the hierarchy for example, chief information officer, where the data request will be forwarded for final approval.
iv. Data Custodianship will be kept by MOCC through GCISC. Data Custodian will have technical role to ensure that deployed NFMS will have proper authorized data access. Furthermore, NCCA will coordinate ensuring data quality and update related issues in coordination with the Provincial REDD+ units.
v. An online data form request is to be developed and placed on the web portal for various users including communities, commercial entities, research organizations & academicians, NGOs and INGOs.
    a. In all cases generic data agreement will be signed (template in Chapter 3.2).
    b. In case where sensitive data is requested by any individual or commercial entity, there will be additional scrutiny such as verification from state institutions such as Securities & Exchange Commission of Pakistan (SECP), PSEB and FBR (Federal Board of Revenue). In few cases, the registration with Survey of Pakistan (SOP) may also be verified.
vi. The form is used to enquire the basic introductory information and will show all the data products as drop-down menus. The product categories can be (but not limited) as following:
    a. SLMS data
        i. LULC (6 categories)
        ii. Maps with different resolution data
    b. Activity data

[1] The functions of the NRO will be taken over by the Pakistan Climate Change Authority established under Section 5 of the Climate Change Act, 2017.

i. Deforestation
ii. Forest degradation
iii. Conservation of forest carbon stocks
iv. Sustainable forest management
v. Enhancement of forest carbon stocks (restoration/afforestation/reforestation)

c. NFI data
   i. NFI plotwise variables for temporary plots (Sensitive Data)
   ii. NFI plotwise variables for permanent plots (Sensitive Data)
d. GHG-I (attach Annexure for more details)
e. Forest Management Data from Forest Compartments
   i. Forest Classification
   ii. Boundary Pillar
   iii. Sample Plot
   iv. Plantation areas and species
   v. Drivers of deforestation and forest degradation

The above-mentioned data is further classified into public and restricted access. Accordingly, there will be a data protocol which will be shared and signed between the requestor and the data owner (MOCC through GCISC in this case).

vii. All the data can be selected through map coverage option on the map. This option can be developed as part of data request portal development where an area on the map can be selected and the required data can be downloaded online, or a request is received to data unit who can process the data and send through DVD/CD.

viii. The above datasets can be provided into desired GIS (vector and raster) and non-GIS formats (csv, excel and pdf etc.).

ix. In case of online data access, OGC web services can be used and data may be provided as WMS, WFS and WCS depending on the type and usage.

x. The form will have a Frequently Asked Questions (FAQ) section which will facilitate end users to answer different queries.

xi. There will be terms and conditions (see Terms and Conditions) which will be uploaded to NFMS web portal.

xii. As per Digital Pakistan Policy 2017 by Ministry of Information Technology, the overall vision of Digital Pakistan Policy is:

a. To become a strategic enabler for an accelerated digitization eco system to expand the knowledge-based economy and spur socio economic growth.
b. Goal No VII says that **Improve the provision of data** to the international rating agencies.

xiii. Following clauses support overall data sharing protocols which equally fit to NFMS:

a. **2.4.** Promote an **Open Digitization infrastructure** for **shared services** including cloud technologies to achieve synergies and economies of scale in both the public and private sectors.
b. **8.1.** Enhance the skills and capabilities within government to evaluate **open source ICT products and services** as an option.
c. **8.2**. Ensure fair consideration of both types of software i.e. **open source** and proprietary during the procurement process. Government IT initiatives should make assessments and cost-benefit and security analysis to determine most appropriate action for each project.
d. **8.3.** Encourage **R&D of "Open Source"** across the country through appropriate means.
e. **17.4** Accelerate adoption of IoT, FinTech, Artificial Intelligence & Robotics and enable cost-effective introduction of new technologies, including **open standards efforts**, targeted federal funding, and impactful public-private partnerships.

As per round-table conference on GIS in physical planning, resource management, governance and business: the need for a national GIS policy and infrastructure (NSDI-national spatial data infrastructure), organized by Planning Commission of Pakistan, following recommendation support the hosting of NFMS:

f. Distribution, dissemination and sharing of GIS data has many constraints and issues; national security, data ownership, intellectual property rights, personal and business confidentiality, and technical infrastructure among many. A National GIS Policy is required to sort out the afore-mentioned issues and lay foundations for an effective GIS data sharing infrastructure. Survey of Pakistan, under current legislation, has been mandated to establish a NSDI (National Spatial Data Infrastructure). Possibilities of a collaborative effort and structure involving users in this respect is to be evaluated.
g. Development of National Spatial Data Infrastructure (NSDI) and **dissemination of GIS data** for government, public, academia and civil Society.
h. A GIS data sharing mechanism and framework would be developed especially where Public Funding and Government Institutions are involved.

3.2. Data Policy and Sharing Protocol

Recommended Description of Data to Be Shared

Upon written consent to the following conditions and restrictions, GCISC-MOCC (hereinafter referred to as the "Owner") will provide the National Forest Data in several formats (such as vector, raster and/or tabular) specified below, as requested (and as available), to the following party: **[PARTY NAME], [whose principal place of residence is at / a [CORPORATE JURISDICTION]** (hereinafter referred to as the "User"

Purpose of Data Sharing. The parties are entering into this agreement, and GCISC-MOCC is granting [PARTY] access to the Data (defined in section [DESCRIPTION OF DATA]), for the purpose of [INSERT SHORT DESCRIPTION OF PUROSE OF THE DATA USE] (the "Purpose").

License Grant to Use Data.

The Owner hereby grants to the User a limited, non-exclusive, non-transferable, and revocable license to access, copy, and use the Data (the "[DELIVERABLE]").

The data provided by the Owner are solely for the User's internal use in the conduct of its daily business affairs

None of the data provided may be reproduced or redistributed without the Owner's prior written permission. This limitation, however, is not intended to restrict the User's distribution of printed map information created from the data.

Access to the data provided by the Owner shall be exclusively for the User and employees of the User. The term "employee" shall mean any person directly employed on a full-time or part-time basis by the User. The term "employee" shall also be construed to mean any contractor, consultant or any similar person or entity hired by the User for a limited purpose.

The User shall require any third-party contractor hired to perform work that utilizes the subject data to agree not to use, reproduce or redistribute the data for any purpose other than indicated in the applicable contract. All copies of the data used by a third-party contractor must be returned to the User upon contract work completion. The provisions of this paragraph shall apply in equal force to any independent contractor the User may choose to employ. The User shall provide any third-party contractor with a copy of this signed agreement and the GCISC-MOCC Data Distribution Policy.

As per GCISC-MOCC Data Distribution Policy, there are two types of clauses. One is public data which is also open while the other is

restricted. The NFMS datasets can be classified as public and restricted.

Liabilities and Limitations for the Accuracy of Data Provided

By signing this Agreement, the User shall become contractually bound to all provisions stated in this Agreement.

Although the owner has verified the data to the best of its ability, the owner makes no representations of any kind as to its completeness or accuracy; nor does it guarantee the complete merchantability or fitness for a particular use, nor are such warranties to be implied, with respect to the data provided under this Agreement.

The User is responsible for understanding the accuracy limitations of the data provided. In particular, alterations and/or manipulation of the original data may adversely affect their accuracy, meaning and design integrity.

To assist in the proper utilization of the data, metadata files are provided, if available. The User, however, assumes all responsibility for the correct use of the data provided and for their interpretation.

The User agrees to hold the Owner, their employees and agents harmless from any claim, suit or proceeding arising out of the use of the data in accordance with this agreement, including indemnification of the Owner and the Government of Pakistan for reasonable expenses incurred in defending such claims.

Production of Printed or Digital Maps/Reports/Publication Products Using Digital Data Provided

The User may reproduce the data in the form of printed products, provided the User abides by this agreement.

Any printed maps, reports or publications created using the data provided by the Owner shall give credit to the primary data owners by using the following statement/disclaimer:

“This [map/report/publication] was created using digital data provided by [Primary Data Source] to the National Forest Monitoring System hosted at GCISC-MOCC. This is a secondary product and has not been verified and is not sanctioned by MOCC.”

The User may not publish the data on any website without written permission from MOCC.

Sharing of the Provided Digital Data with Other Persons or Entities

If at any time during the course of this Agreement, the User determines that it is necessary to share portions of the data with a person or entity not employed by the User as a consultant, contractor or any similar

person or entity for a limited purpose, the User shall first request permission from the GCISC-MOCC before sharing any portion of the data, unless otherwise committed by this Agreement or as required by law. Any such request shall be in writing to the GCISC-MOCC and shall specify the persons or entities the User wishes to share the data with and the reasons why such sharing of the information is necessary. Permission for the User to share the data provided with other parties shall not be unreasonably withheld if such sharing of the information is necessary to further legitimate governmental purposes. Commercial or revenue-generating uses of the data shall not be considered a legitimate purpose until allowed by GCISC-MOCC.

The undersigned hereby accepts and agrees to be bound by the terms and conditions set forth in the Data Sharing Policy attached hereto and made part of this agreement. It is fully understood that pursuant to this agreement, the undersigned is permitted to utilize digital information provided by GCISC-MOCC, solely in the conduct of its own daily business affairs. Any other use, unless with prior written permission from GCISC-MOCC, shall be deemed unauthorized and punishable by law.

GCISC-MOCC makes no representations of any kind, including but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied, with respect to data furnished hereunder. GCISC-MOCC assumes no responsibility to maintain them in any manner or form.

I have the authority to legally obligate the User to the terms of this agreement:

NAME _____

SIGNED _____

TITLE _____

DATE _____

3.3. Terms and Conditions on using NFMS Web Portal

NFMS Terms of Service

This Agreement was last modified on May 13, 2018.

The NFMS Data Repository is provided as a service for the purpose of facilitating GIS data sharing between different national and provincial stakeholders.

Please read these Terms of Service completely and carefully. This page documents the terms and conditions attached to the use of the geospatial data repository in any way at [*e.g. www.nfms-pakistan.org*]

By using or accessing the spatial data repository in any way, viewing or browsing the content, or adding your own content to the repository, you are agreeing to be bound by these Terms of Service.

Format

GIS data can be uploaded in ESRI shapefile or geoTIFF format unless otherwise specified. Datasets will be compatible with all standard GIS platforms. If GIS software is not available it is recommended to use a free GIS viewer, such as Quantum GIS.

Instructions for Use

- GIS data or maps and tabular data derived from GIS data acquired from the GIS Data Repository may be used in publications and presentations, provided that credit is given to the data provider listed in the related metadata.
- If you are a registered user of the NFMS at "url", you shall maintain accurate user account information concerning your identity including your first and last name and e-mail address.
- If you are a registered user of the NFMS at "url", you acknowledge and agree that e-mail is an acceptable means of communication with you, and you agree to accept e-mails from either admin email + website and shall not block e-mails originating from these sources.

Restrictions

- Access to data posted does not constitute a transfer of any ownership or interest in the GIS data.
- All the relevant stakeholders shall use the GIS data exclusively for intended use.
- In order to maintain data quality and consistency, and avoid any legal consequences regarding data, the user agrees that GIS data will not be transferred, sold, or otherwise made available to a 3rd party without the expressed written permission of original owner of data or paid acquisition of GIS data.

Termination

As a condition of your use of the NFMS, you will not use the NFMS for any purpose that is unlawful or prohibited by these terms and conditions. You may not use the NFMS in any manner that could disable or overburden the server or interfere with any other party's use of the Repository. You may not attempt to gain unauthorized access to any services, other accounts through hacking, password mining or any other means. You may not obtain or attempt to obtain any materials or information through any means not intentionally made available through the Repository. In any such case the MOCC reserves the right to terminate your account or remove any unauthenticated data from site, without any advance notice. User will be notified after removal through e-mail.

Changes to This Agreement

MOCC reserves the right to modify these Terms of Service at any time. We do so by posting and drawing attention to the updated terms on the Site and by highlighting them under Announcements tab. Your decision to continue to visit and make use of the Site after such changes have been made constitutes your formal acceptance of the new Terms of Service.

Therefore, we ask that you check and review these Terms for such changes on an occasional basis.

4. NFMS FUNDING ARRANGEMENTS

It is critical to carry out a detailed assessment of the funding available and needed to ensure the long-term sustainability of the NFMS. The funding analysis will serve as a domestic tool to support requests for national government funding and as a tool for requesting international support on specific work areas.

To the extent that REDD+ mechanism would result in results-based payments, thought should be given to ensure the self-financing of the NFMS and the fair allocation of available funds (to the different technical units, equipment maintenance, security of jobs, staff training, etc.). The funding allocation mechanism for operating and maintaining the NFMS are to be discussed with all relevant stakeholders.

Pakistan needs to develop progressively and operationalize the three pillars of the NFMS-MRV, namely SLMS, NFI and GHG-I over the three phases of REDD+. The REDD+ readiness activities (Phase I) are being completed and the country is moving to the REDD+ implementation (Phase II). By the third phase of REDD+ Pakistan must have a fully functional NFMS-MRV system to achieve funding from the performance-based funding schemes.

R-PP (2013) provides projected features and capacity for the major NFMS elements. The following sub-chapters provides the summarised assessment which activities, development and resources are needed to proceed from the readiness phase (1) producing the NFMS design towards the REDD+ implementation phase (2) in the short-term.

4.1. Satellite Land Monitoring Systems

Current **(Phase 1)**	**Short-term objective** **(Phase 2)**	**Long-term objective** **(Phase 3)**
Institutional framework decided. SLMS methodology standard is prepared, consulted and trained at national level.	Active participation in national land use categorization	Periodic re-assessment of Forest Land sub-classification
Land use and cover maps for 1996, 2000, 2004, 2008, 2012 and 2016 with 6 IPCC classes	Full sub-classification on Forest Land, using IPCC Approach 3	Full assessment of Forest Land sub-category transfers. Land use and cover mapping repeated every 4 years
Deforestation and forest degradation assessment conducted with reported climate zone and provincial results for 1996-2000, 2000-2004, 2004-2008, 2008-2012, 2012-2016	Sampling approach based on high-resolution optical satellite imagery to assess degradation, specifically in relation to field data collection in relevant areas	Sampling approach as before, focusing on hotspots that have been identified from previous assessments.

Activities:

- Land use and cover mapping next time by 2020

Resources:

- 2 GIS and Remote Sensing Experts trained for the SLMS standard protocols in each FD
- VHR data for more detailed change assessments and degradation assessment by forest type

It is recommended to have 1 dedicated forest inventory expert (supervisor level qualifications) and 2 dedicated GIS experts as full-time employees to prepare and coordinate the provincial forest inventory and mapping campaigns. Besides there is a need for temporary NFMS staff members to assist inventories and mapping tasks. These temporary staff members can be acquired through relocations within the forest

departments or they can be sourced from outside. The number of needed persons depend on the desired schedule of activities. The desired training outlines is presented in the capacity-building report.

4.2. National Forest Inventory

Current **(Phase 1)**	**Short-term objective** **(Phase 2)**	**Long-term objective** **(Phase 3)**
The NFI designed and measurement protocol defined. The national forest inventory design also covers lands of the state and non-state forest owners.	Fully operational in most state-owned forests for major forest types. Support for implementation by non-state forest owners.	Fully operational in all state-owned forests. Protocols developed and operational for all forest types. Implemented by non-state forest owners country wide.

Activities:

- NFI permanent sample plots remeasured by 2021, and every 3 years Temporary sampling plots measured with intensified sampling intensity (i.e. 5'x5', 2.5'x2.5', 1.25'x1.25) for specific forest types under interest
- Allometric equation development for the main species by forest types

Resources:

- **I**nventory team leader supported by two GIS and remote sensing officers (see SLMS) in each FD
- Research team to carry out research for allometric equations

4.3. National GHG Inventory and reporting

Current (Phase 1)	Short-term objective (Phase 2)	Long-term objective (Phase 3)
Emission/removal factors have been developed based on pilot NFI inventory by climate zones and provinces	Key category assessment for carbon pools completed for major forest types. Emission factors for use outside of state-owned forests developed for major forest types.	Key category assessment for carbon pools completed for all forest types. Emission factors for use outside of state-owned forests developed for all forest types.
FREL/FRL has been developed for 1996-2016	Carbon stock estimation where data supports it.	Carbon stock estimation in all forests and assessment against applicable FREL or FRL to establish performance.
FREL/FRL data included forest cover changes available for 1996-2016 The forest sector emission and removal factor data are stored in NFMS to be used in the next report.	Activity data reported on the basis of land use categorization. Emission factors derived for major forest types.	Activity data reported on the basis of land use categorization Emission factors derived for all forest types. NFMS will generate full report on reduced emissions and enhanced removals on Forest Land.

Activities (national level):

- Updating the national emission and removal factors

- Combining the activity data and emission data for 2020
- Independent verification of the field reference data
- Uncertainty assessment

Resources:

- One officer appointed by MOCC/NCCA

4.4. REDD+ Monitoring

Current (Phase 1)	**Short-term objective (Phase 2)**	**Long-term objective (Phase 3)**
No systematic monitoring for fuelwood and timber harvesting	Internal displacement of emissions within the forestry sector assessed from field data on forest degradation (e.g. fuelwood, timber), specifically in conditions of forest degradation.	All Forest Land is monitored by the NFMS so no domestic leakage within the forestry sector. Cross-sectoral domestic leakage (e.g. with energy sector) assessed at the national level. International leakage assessed through external studies for which NFMS data will be made available.
Carbon registry allows registering the projects and monitoring interventions using NFMS	Where data is available from REDD+ projects, effectiveness of intervention strategies under specific environmental conditions is evaluated.	All strategies and interventions are assessed for their effectiveness and performance, with due regard to environmental conditions.
NFMS designed to monitor effectiveness of NRP interventions	All NRP strategies and interventions are assessed for their effectiveness and performance, with specific reference to the degree by which those interventions contribute to the achievement of policies. This explicitly includes assessment of the impacts of benefit distribution strategies.	Where data is available, effectiveness of NRP interventions is evaluated, with specific reference to the degree by which those interventions contribute to the achievement of policies.

Activities:

- Systematic monitoring drivers of deforestation and forest degradation, and causes behind
- Monitoring sustainable forestry and carbon stock enhancement activities
- Spatial assessment for reduced emissions, potential displacement or leakage
- Analysis for the effectiveness and performance of the REDD+ strategies and intervention

Resources:

- Provincial forest management information systems as sources for forest management data
- Analysis supported by a GIS expert (see SLMS) at provincial and national level
- REDD+ Thematic Working Groups to review the national strategies and interventions

4.5. MBIGS/SIS

Current (Phase 1)	**Short-term objective (Phase 2)**	**Long-term objective (Phase 3)**
The SIS/MBIGS institutional framework and indicators linked with the NFMS system design	Safeguards are integrated into the design of the NFMS and supported according to the level of development of the NFMS.	All safeguards based on resource data and NRP participation supported by the NFMS.

Activities:

- Data collection in REDD+ implementation areas and forest compartments
- Compilation of secondary source data
- Preparing provincial reports
- Aggregation the reports at the national level

Resources:

- Forest guards at FD to collect data in field
- Provincial REDD+ focal points
- MBIGS/SIS expert at MOCC/NCCA

4.6. NFMS Webportal

Current (Phase 1)	Short-term objective (Phase 2)	Long-term objective (Phase 3)
NFMS Web-portal have been developed and installed at GCISC for providing data access to stakeholders and general public	Non-state implementers of REDD+ projects have access to the NFMS for managing their forest resource data. General public will have access to overview data, with detail down to the lowest possible level whilst still maintaining confidentiality for forest owners and project implementers.	Non-state implementers of REDD+ projects have access to the NFMS for managing their forest resource data. Access to special users (e.g. research) granted on an individual basis. General public will have access to overview data, with detail down to the lowest possible level whilst still maintaining confidentiality for forest

Activities:

Operations

- Updating the data repository with the data from province and other sources
- Responses to any data related queries in coordination with the provincial REDD+ units.
- Ensuring Standard Operational Procedures are being followed
- Data User Access Control at provincial and federal levels
- Detailed Training Manuals for End-users as well as Technical Users
- Implementation of Partnership Agreements/Modality
- User training events, awareness seminars across the country

Technical Backend-Support

- NFMS handling including software source codes and design for future customization as per the need
- Complete Hardware maintenance PLAN
- Fixing bugs on LIVE data feed

- Dedicated Onsite and Offsite Support
- NFMS Scalability with more data coming IN to make it sustainable
- To prepare NFMS to fit with National Spatial Data Infrastructure (NSDI)
- To add the additional modules in NFMS as per long term goals of REDD+

Resources:

- One data administrator to handle the data requests and data exchanges
- Chief data officer to support the activities
- External system consultant for maintenance and development support

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6. Annexes

Annex 1 Decision Process for Definition of Forest

Background

In the past, there have been attempts to formalize the 'nationally accepted' definition of a forest that has as yet no formal and legal recognitions; the reason being that there are no such definitions specified in any national or provincial policies, legal instruments or strategies (Government of Pakistan 2015). With this backdrop, the process of formal definition of the forest and endorsing with the national consensus was reinitiated under this project "Develop Forest Reference Emission Levels/Forest Reference Level and National Forest Monitoring System (NFMS)-Measurement and Reporting and Verification (MRV) System for REDD+". A key reference and tool[1] to support design decisions related to the definitions of forest, land use and land use change categories for the National Forest Monitoring System for Islamic Republic of Pakistan was prepared to facilitate the decision-making process.

The decision on the definition was made through a national consensus process steps involving the Federal Entities, Provincial Forest Departments, academic and research institutions and other related stakeholders. The process for this national consensus and endorsement involved:

- review of international best practices for allowable thresholds for minimum area, minimum crown cover and minimum height;
- determination of scope of activities;
- determination of Remote Sensing thresholds and approaches for detecting changes in land use, forest canopy cover/height/area;
- assessment of country situation regarding thresholds;
- assessment of cost and benefits of available options;
- finalize forest definition;
- stakeholders' discussion and consensus; and
- national endorsement

The process of this key decision of Forest Definition was initiated during the Inception Workshop and the consensus building process continued through various stages.

[1] The document is entitled "Briefing Note for Definition of Forest Land and Other Land Use Classes and their Endorsement at the REDD+ Working Group Meeting on 7th-8th August 2017".

Stages	Decision Process	Timeline
Stage 1	▪ Brainstorming Session on Land Cover and Activities	Inception Workshop (13-14 February 2017)
Stage 2	▪ Group Discussion on harmonization of existing land use classification with the IPCC Land Use Classes ▪ Propose a consistent, comparable sub classes for forest types, applicable throughout the territory of Pakistan	Inception Workshop (13-14 February 2017)
Stage 3	▪ Key stakeholder consultation meetings at MOCC National REDD+ Office, Provincial Forest Departments, Pakistan Forest Institute and other stakeholders ▪ Key Informant Interviews Checklists on National Forest Inventory (NFI) ▪ Key Informant Interviews Checklists on Satellite Land Monitoring System (SLMS) ▪ Key Informant Interviews Checklists on Green House Gas inventories (GHG-I)	Visits to Provincial FD's, national and provincial stakeholders, academic institutions, other stakeholders (Annex 1) (March-June 2017)
Stage 4	▪ Preparation of Briefing Note for Definition of Forest Land and Other Land Use Classes as a decision support tool ▪ Circulation and review of the briefing note to the provincial FDs and relevant stakeholder	4-6 August 2017 (before the REDD+ WG Meeting)
Stage 5	▪ Presentation and REDD+ Working Group Technical Meeting ▪ Discussions amongst the key stakeholder groups ▪ Consensus amongst the stakeholders' groups ▪ Decisions by the stakeholders' groups ▪ Ratification by all the stakeholders ▪ Endorsement by the MOCC ▪ Notifications to the provincial governments is in process	Meeting of REDD+ Working Groups (7-8 August 2017) Notification Letter from the MOCC is attached in Annex 3

Decision on Forest Definition

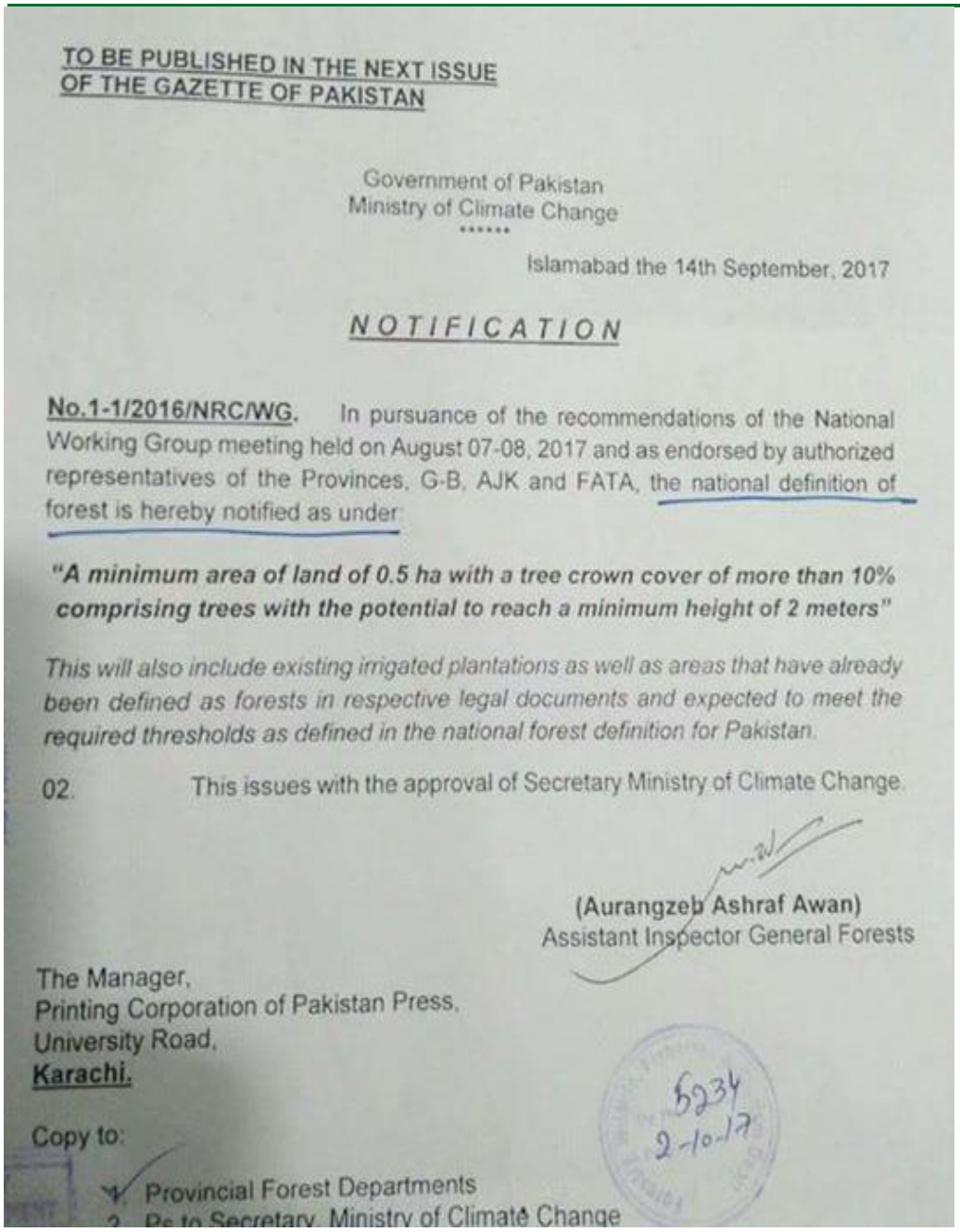
The final Stage 5 comprised of the REDD+ Working Group discussions, consensus building, decision on the definition and ratification by the REDD+ Working group. The key decision was made on the 'National Definition of the Forest' with these parameters and their rationale:

Parameter/Threshold	Description/Rationale
Minimum area of 0.5 ha	• Historic data (remote sensing and inventory) for reference years available • Institutional capacity required for processing and analysis of remote sensing and inventory data exists • Cost effective due to freely available remote sensing data (e.g. Landsat, Sentinel 2) • Easy to estimate and make comparisons using consistent method • Small sized land holdings in hilly regions can be included
Minimum crown cover of 10%	• Pakistan has low forest cover • Scrub forest and Shrubland to be included
Minimum height of 2 m	• Vegetation of dry and arid climate to be included • Growth rate of forest is low in Pakistan • Scrub forest to be included

- Besides these threshold parameters, inclusion of Plantations was also discussed and decided. ,

  The definition was endorsed by all the provincial representatives and was agreed upon and officially notified as the National Forest Definition by the Government of Pakistan/Ministry of Climate Change on the date of **14 September 2017.** The notified forest definition is as follows.

  .



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Government of Pakistan
Ministry of Climate Change
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Islamabad the 14th September, 2017

NOTIFICATION

No.1-1/2016/NRC/WG. In pursuance of the recommendations of the National Working Group meeting held on August 07-08, 2017 and as endorsed by authorized representatives of the Provinces, G-B, AJK and FATA, the national definition of forest is hereby notified as under:

"A minimum area of land of 0.5 ha with a tree crown cover of more than 10% comprising trees with the potential to reach a minimum height of 2 meters"

This will also include existing irrigated plantations as well as areas that have already been defined as forests in respective legal documents and expected to meet the required thresholds as defined in the national forest definition for Pakistan.

02. This issues with the approval of Secretary Ministry of Climate Change.

(Aurangzeb Ashraf Awan)
Assistant Inspector General Forests

The Manager,
Printing Corporation of Pakistan Press,
University Road,
Karachi.

5234
2-10-17

Copy to:

1. Provincial Forest Departments
2. PS to Secretary, Ministry of Climate Change

Annex 2 Sources of information for the drivers of deforestation and forest degradation events

Drivers of Deforestation and Forest Degradation	Source for information to detect the degradation and deforestation event and its extent	Verification body
Infrastructure Development	Forest Department Roads Department / Highway Local Government Department Department of Physical Planning and Housing Land use planning and development department PWD (Hydel Projects) LGRD Forest Conservation Committees Revenue Department (Irrigation, Agriculture Departments & NGOs) National/Provincial mapping agencies ("urban unit") and academic institutions , Political administration Police Department (FATA Levies)	Revenue Authority Land use planning and development department Irrigation Department Highway department Local government Forest Department
Settlements Habitation Urban / Shanty town expansion	Forest Department (field staff) Revenue Department Municipal Corporation PDA/LDA (Provincial Development Authorities) Local Community Researchers National mapping agency	Town Planning Department Revenue Department Municipal corporations / committees / local govt. Forest department
Mining	Forest Department (field staff/guard; illegal cases) Revenue department (illegal cases) Mining Department (requests NOC from forest Department in legal cases)	Town Planning Department Mining department Forest Department

	Small Industries Department Community members Geological survey of Pakistan	
Forest fires	Forest Department (Forest Guards) Local community (member) Police reports Meteorological department Political Administration	Police and disaster management staff Forest officer
Commercial agriculture expansion	Local Community Forest Department (field staffs) Development Authorities (concerned, prior request in legal cases (Land) Revenue Department Town and City Management Agriculture Department Crop Reporting Services	Local Administration Agricultural Department Forest Officer (GIS, forest history files/records)
Subsistence agriculture expansion	Local Community Forest Staff (Forest Department) Agriculture Department (Land) Revenue Department (Patwari) Crop Reporting Services	Local Administration Agricultural Department Forest Officer (Compartment history files) Revenue Department Police (reports)
Small-scale agricultural practice expansion	Local Community Forest Staff (Forest Department, (compartment / forest history files / police reports) Agriculture Department (field officer) (Land) Revenue Department (Patwari) Town and City Management, provincial mapping unit	Local Administration Agricultural Department Forest Department Revenue department
Encroachment	Forest Department (staff/guards)	Local development authorities

	Local Community Revenue Department Police Journalists Area (Provincial) Development Agencies	Forest Department (Demarcation unit of FD; GIS) Revenue department
Forest clearing for security purposes	Forest Department (field staff) Revenue Department Community Army-Police (sometimes) Security Agencies Govt. officials	Local development authorities Forest Department (ground verification) Revenue Department
Unsustainable timber and fuelwood extraction	Forest Department (field staff/guards) AKLASC (Azad Kashmir logging and saw mills corporation, timber) Local community (member) Police or another law enforcing agency (FATA levies) NGOs Media (In case of firewood extraction most people as beneficiaries silent)	Local development authorities Forest Department (forest office, damage reports ground verification, timber assessment reports, working plans /management plan data)) PFI Local community
Fish pond establishment	Fishery Departments Forest Department (field staff) Local community Irrigation Department WAPDA	Local development authorities Forest Department (Staff/Officer)
Water-logging activities	Agriculture Department Land Department Forest Department (field staff) Local Farming communities Soil Survey of Pakistan national mapping agency Irrigation department	Local development authorities Forest Officer (forest inventory reports)
Free / uncontrolled	Forest Department / Forest Guards (local staffs)	Any local person Forest officer (Surveys conducted by forest

livestock grazing Overgrazing and browsing	Livestock Department Revenue Department Local Community (members)	department and livestock, damage and other reports)
Land lease / hand over	Govt Dept/Provincial Development Agencies Municipal Department Forest Department (field staff/officer) Revenue Department Small industries Tourism dept. Mining department	Revenue Department
Hotel industry development	Forest Department (field staff) Tourism Department Local community PPH TDCP Local development agencies	Beneficiary Forestry Officer (spot verification/GIS map/forest records, impact assessment reports, notes)
Unscientific forestry operations and management	Forest Department (Forest officer) Community Media Local administration	Forest Department (Staffs, assessment, evaluation, offence case reports, department data / management plans) PFI
Atmospheric pollution	Govt. dep EPA Environmental Department Meteorological department Transport authority Small industries department Media	Forest Staffs Met Department
Freshwater pollution	Govt Dept Agriculture Department Fisheries Department (Flood &) Irrigation Department Municipal department EPA Forest Department Health Department	Forest Department Environmental Municipal Irrigation EPA Public Health
Floods	Flood Relief Department Flood Warning Centres Forest Department	WAPDA Meteorological Department

	WAPDA PDMA+NDMA IRSA Irrigation Department Media Owners/Users GBOMA Pakistan Meteorological Department FATA Disaster Authority (FOMA)	
Forest diseases, and pest attacks	Forest Department (DFO, field staff) PFI Pest Control Department Community	Forest Department (Staffs/Officer) PFI
Landslide impact areas	Local community Forest Department (field staff) UNDP NDMA Geological survey of Pakistan FOMA	Road Maintenance bodies Forest Department (Forest officer) Survey of Pakistan AJK Land Use Planning RFO Communication & Works Department
Heavy snowfall impact area	Local community & members Forest Department (Staff) NDMA, PDMA Pakistan Meteorological Department	Climate / Met. department National News Forest Officer
Earthquake impact area	Local community & members Forest Department (Staff) Revenue Department Disaster Management Authority NDMA, PDMA (GBDMA) Meteorological Department Geological department Political administration	National Disaster Management Department / PDMA Forest Officer
Run off/erosion impact area	Local community & members Forest department (Staff) WAPDA NDMA	Forest Officer

	Pak. Meteorological Department Irrigation Department Soil conservation Department	
Drought impact area	Local District Administration NDMA+PDMA Disaster Management Authority Locals/Community Agriculture/Forest Department (Staff; Rangeland officer) Revenue Department Pak. meteorological department	Forest Officer Met Department
Oceanic intrusion and tsunami impact area	Locals / Forest Staff Pak. Meteorological department Pak. Navy. Coastal Development Authority / Coastal Management Department Marine Fisheries Department Sea Port Authorities Disaster Management Authority Revenue Authority WMO WAPDA	All national Dept.

Annex 3 Pilot NFI results

Forest type	N:o clusters	Mean Carbon Density, AGC+BGC (C ton/ha)
Littoral and swamp forest (Mangroves)	11	5.2
Thorn	14	7.8
Riverine	3	19.0
Broadleaved	16	13.8
Pine	4	30.3
Moist Temperate	8	88.0
Dry Temperate	9	23.2
Irrigated Plantation	9	20.8
Other land (tropical)	12	1.4
Other land (sub-tropical)	6	3.0
Other land (temperate and alpine)	5	1.6
Other land (farm plantation)	4	10.5

The more detail inventory results by plots and provinces are provided in separate Excel files.

Annex 4 Height-Diameter models developed in scope of pilot national forest inventory

d = diameter at breast height

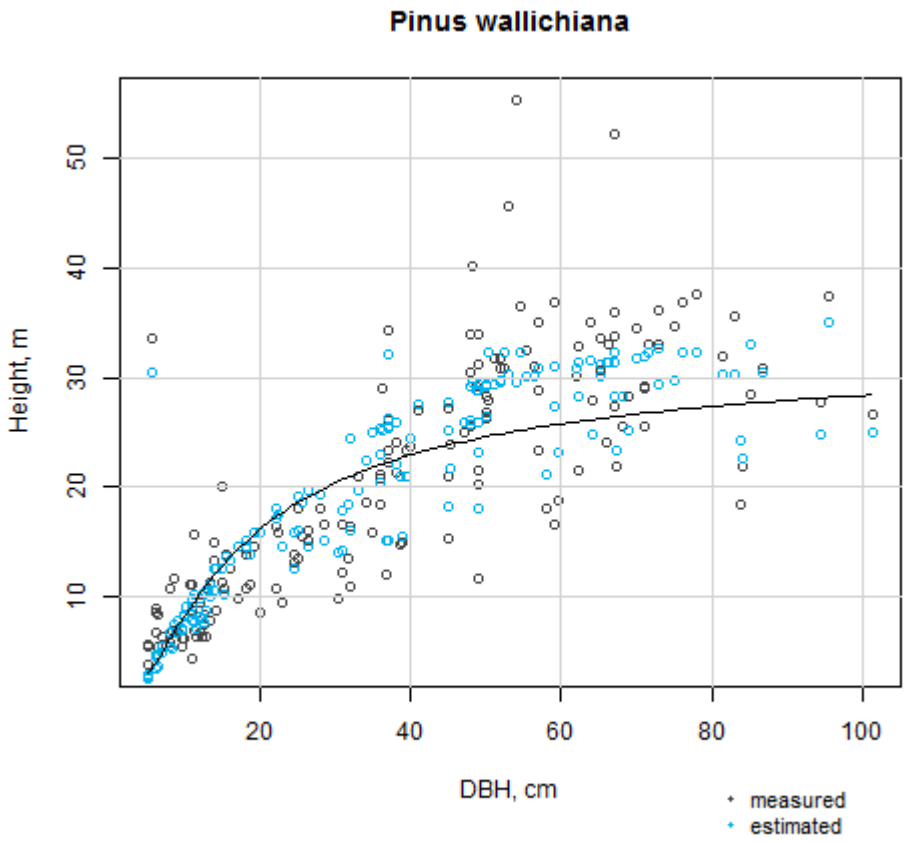
h = tree height

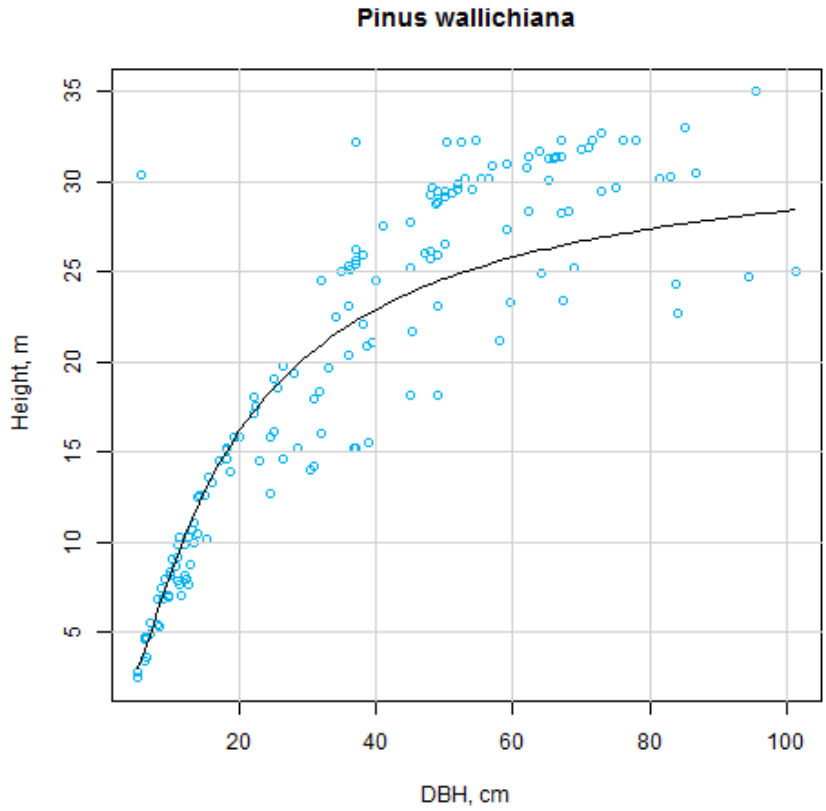
$h = a*\exp(-b*d^{-1})$ (Korf model)

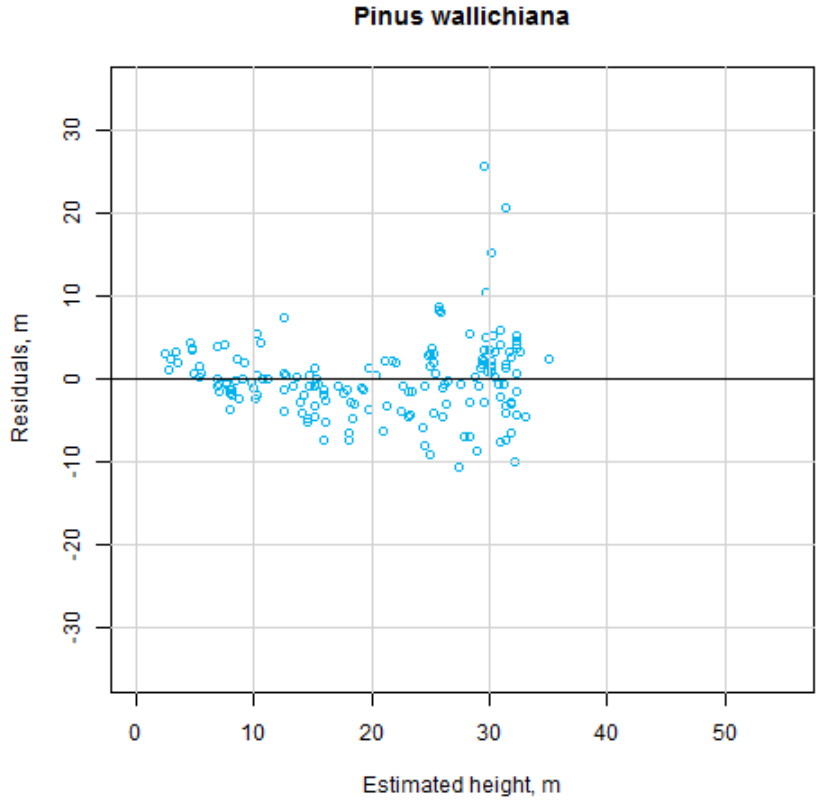
Pinus wallichiana

Plot id (cluster00000plot)	a	b
344000003	0.450622	2.415701
427000001	-0.759492	1.579843
427000002	-0.283345	-14.654393
427000003	-3.652954	-0.979018
427000005	5.055100	0.565550
444000001	3.112806	1.639799
444000002	4.180526	2.157172
444000003	10.144255	5.144232
444000004	6.656569	0.683536
444000005	7.771981	2.653048
460000001	-0.470101	0.148539
460000002	-2.951408	-0.569941
460000003	-6.019667	-2.322895
460000004	8.158795	2.051501
460000005	8.882224	2.630905
486000004	-2.562233	2.936815
5839000001	-6.278101	-1.386532
5839000002	5.377302	-2.347273
5839000003	-4.182941	-0.798186
5839000004	-9.473690	-1.821150
7057000001	-2.069081	-0.411532
7057000005	-4.436705	0.069929

7864000001	-10.709663	-0.225913
7864000002	-7.983445	-0.135408
7864000003	-2.418713	-1.670066
7864000005	4.461359	2.645737

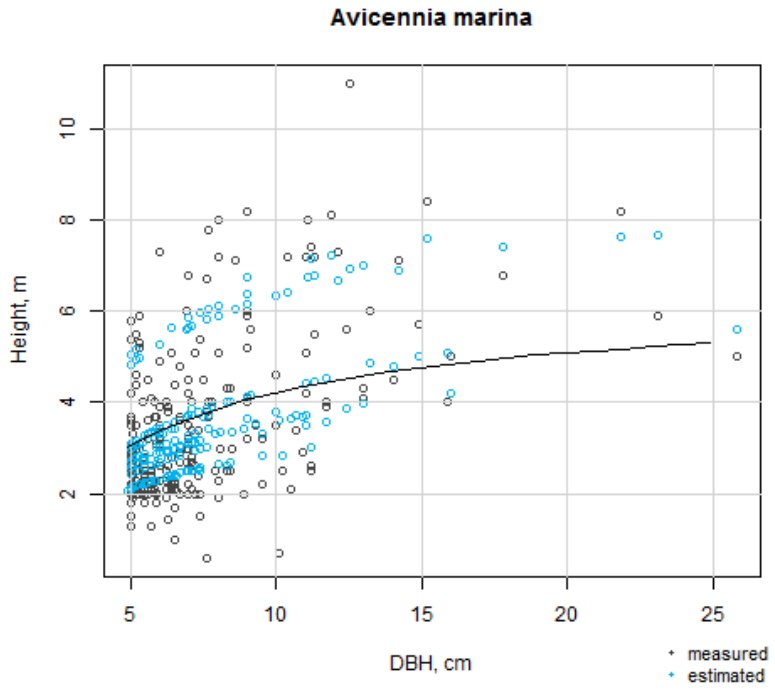


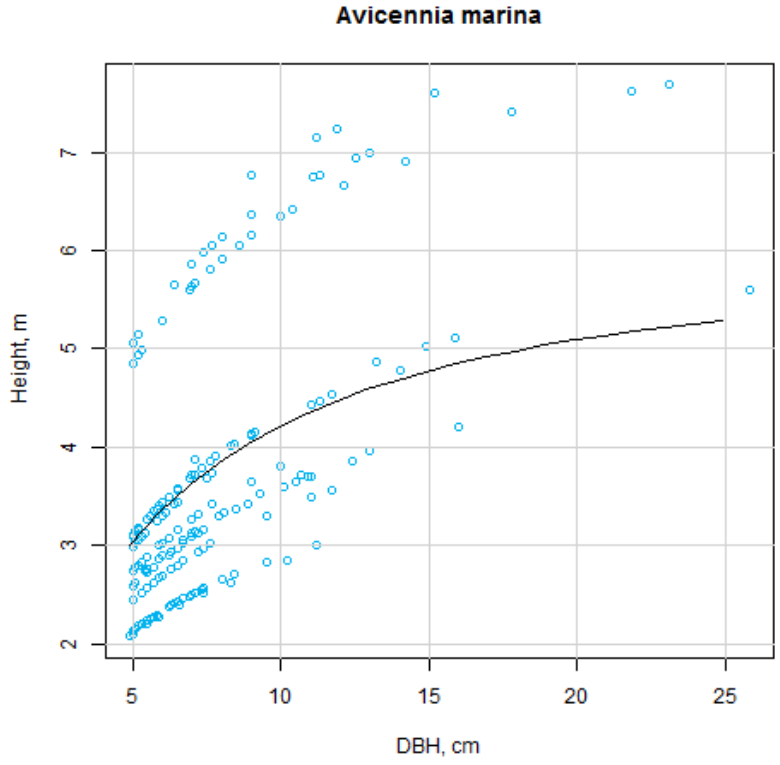

Pinus wallichiana
Height, m
5
10
15
20
25
30
35
20
40
60
80
100
DBH, cm

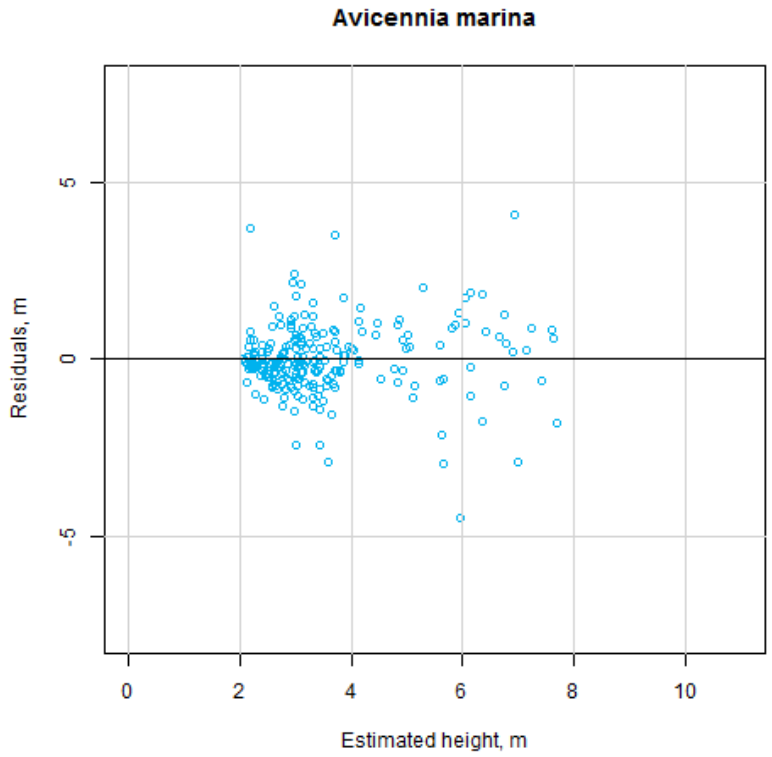

Pinus wallichiana
Residuals, m
-30
-20
-10
0
10
20
30
0
10
20
30
40
50
Estimated height, m

Mangrove species (Avicennia marina, Rhizophora mucronata, Ceriops tagal)

Plot id (cluster00000plot)	a	b
2921000001	-1.975841	1.535049
2921000002	-0.824459	0.640320
2921000003	0.291837	-0.226858
2921000004	-0.831055	0.646036
2921000005	-1.132542	0.880057
2946000001	0.110442	-0.085778
2946000002	0.091043	-0.070400
2946000003	-0.530311	0.412010
2946000004	-0.762467	0.592553
2946000005	-0.091864	0.071379
113279000001	2.460260	-1.911661
113279000003	-1.866548	1.449998
113279000004	2.803129	-2.177816
113279000005	2.258375	-1.754890


Avicennia marina
Height, m
2
4
6
8
10
5
10
15
20
25
DBH, cm
measured
estimated

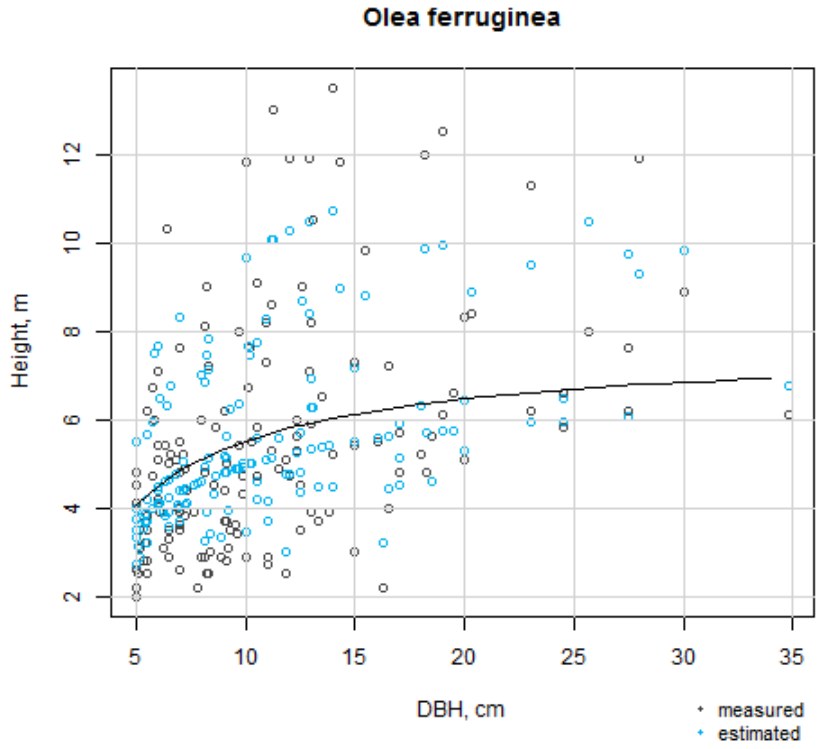

Avicennia marina
Height, m
2
3
4
5
6
7
5
10
15
20
25
DBH, cm

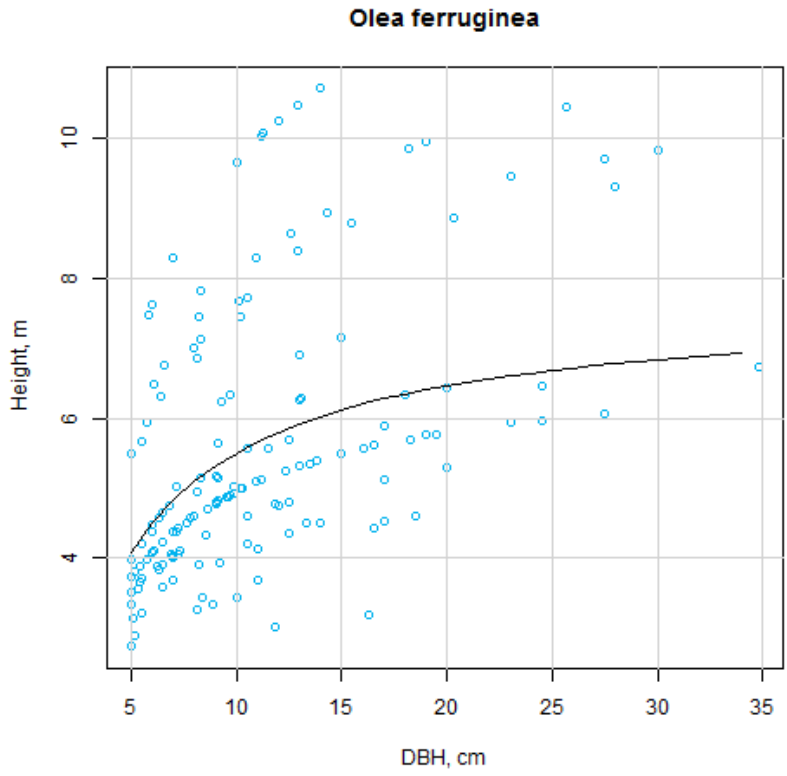


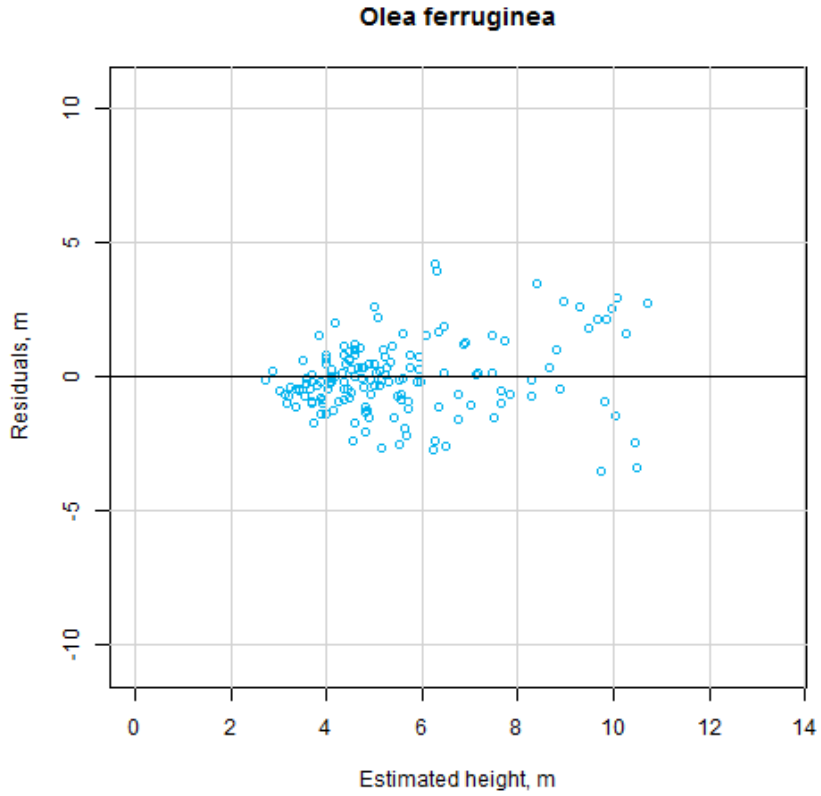
Olea ferruginea

Plot id (cluster00000plot)	a	b
485000001	3.444128	-0.000029
485000002	3.200836	-0.000027
485000003	6.336728	-0.000052
485000004	4.418702	-0.000036
485000005	3.882507	-0.000031
486000002	2.934151	-0.000023
519000002	0.327096	-0.000003
519000003	3.258866	-0.000028
536000001	-0.306143	0.000003
536000002	2.912632	-0.000024
536000003	0.474386	-0.000004
538000005	1.360789	-0.000011

887000001	-2.897337	0.000024
887000002	-2.116142	0.000017
887000004	-2.007323	0.000016
887000005	-3.128718	0.000026
927000001	-0.290455	0.000002
927000002	-0.829844	0.000007
927000003	-0.025263	0.000000
927000004	-0.716322	0.000006
927000005	-0.229083	0.000001
929000001	-1.440384	0.000012
929000002	-2.239088	0.000019
929000003	-0.844787	0.000007
929000004	-1.479782	0.000012
929000005	-0.814328	0.000008
14115000005	-0.504991	0.000004
16141000001	-2.332397	0.000019
16141000002	-1.334224	0.000011
16141000003	-2.072365	0.000017
16141000005	-3.931616	0.000032
17562000002	-1.291470	0.000011
17562000004	-1.718758	0.000014

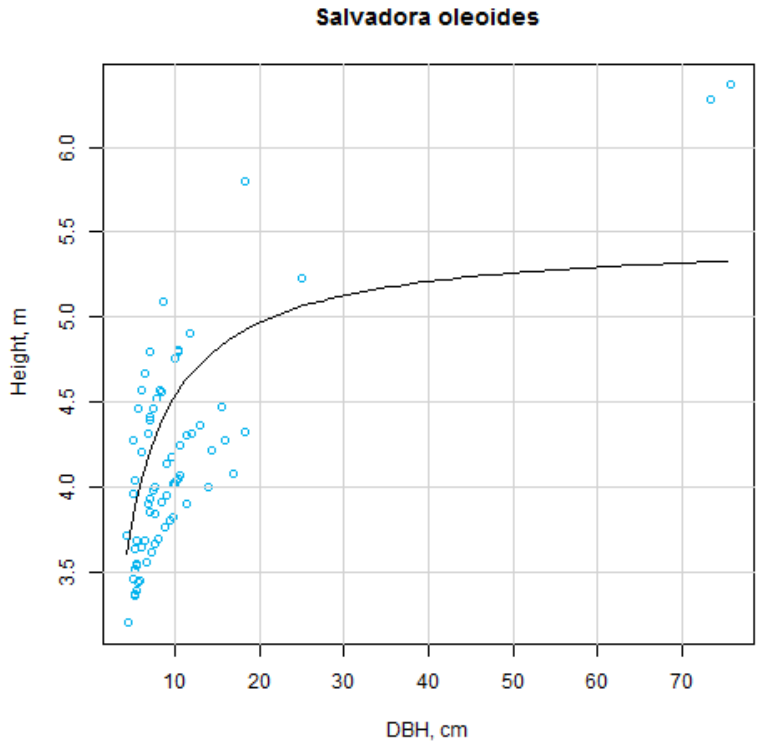

Olea ferruginea
Height, m
2
4
6
8
10
12
5
10
15
20
25
30
35
DBH, cm
measured
estimated

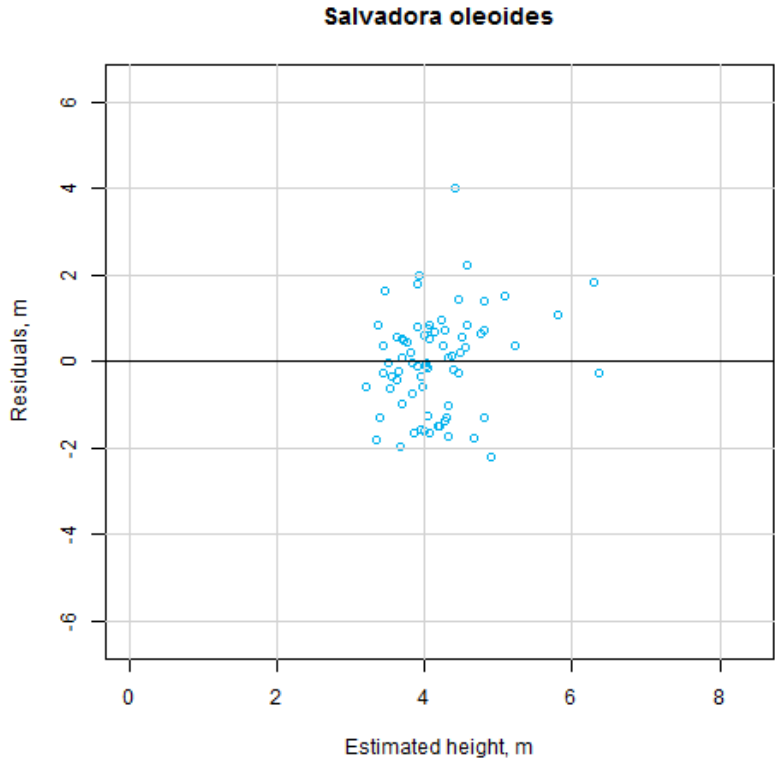

Olea ferruginea
Height, m
4
6
8
10
5
10
15
20
25
30
35
DBH, cm

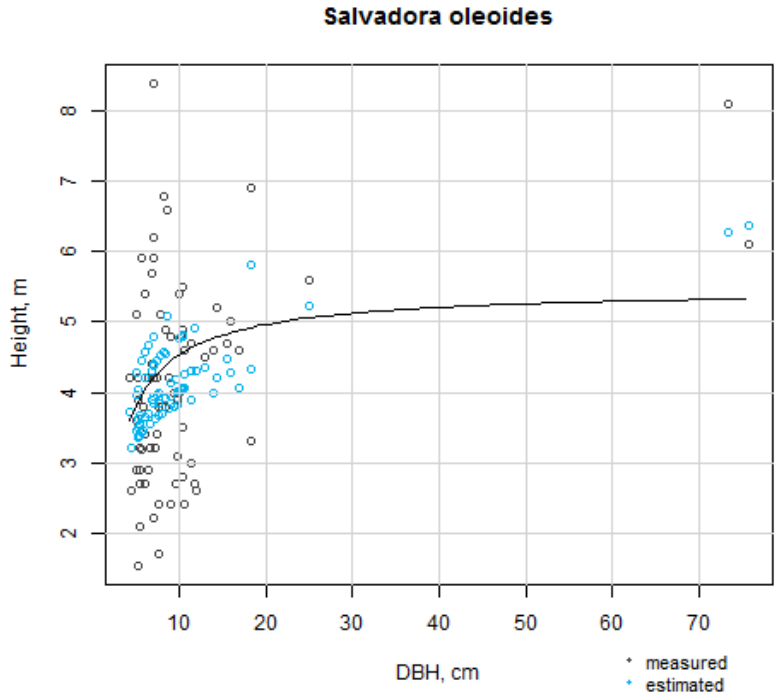


Salvadora oleoides

Plot id (cluster00000plot)	a	b
2497000005	0.347058	0.096325
2606000001	-0.996175	-0.277715
2606000002	-0.728232	-0.203911
2606000003	-0.475604	-0.133141
2606000005	-0.458329	-0.128406
2852000001	-0.588687	-0.164457
2852000002	0.188664	0.052850
2852000003	1.010010	0.283143
21799000003	0.341558	0.095672
21799000004	1.094300	0.305677
21799000005	0.265437	0.073964


Salvadora oleoides
Height, m
3.5
4.0
4.5
5.0
5.5
6.0
10
20
30
40
50
60
70
DBH, cm

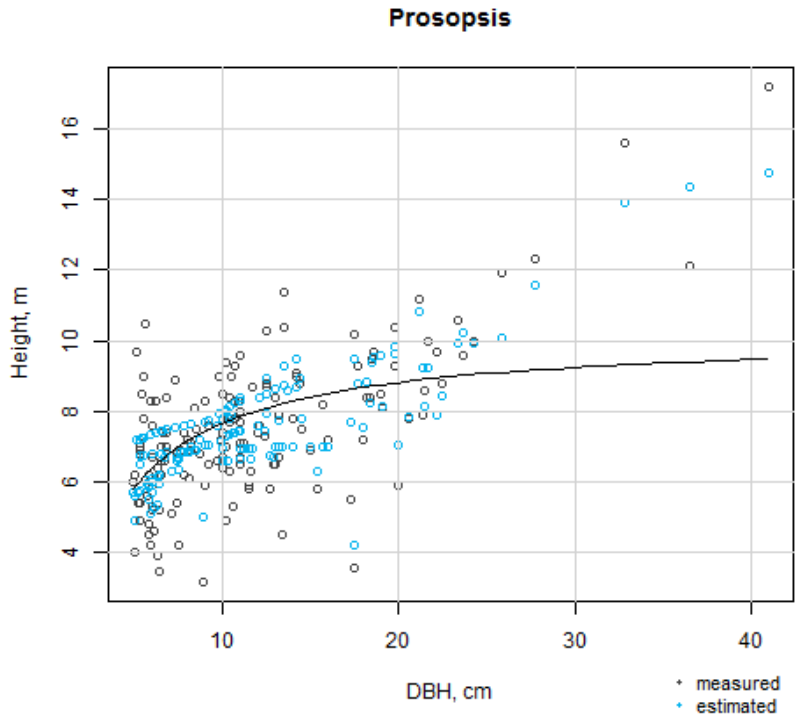

Salvadora oleoides
Residuals, m
-6
-4
-2
0
2
4
6
0
2
4
6
8
Estimated height, m

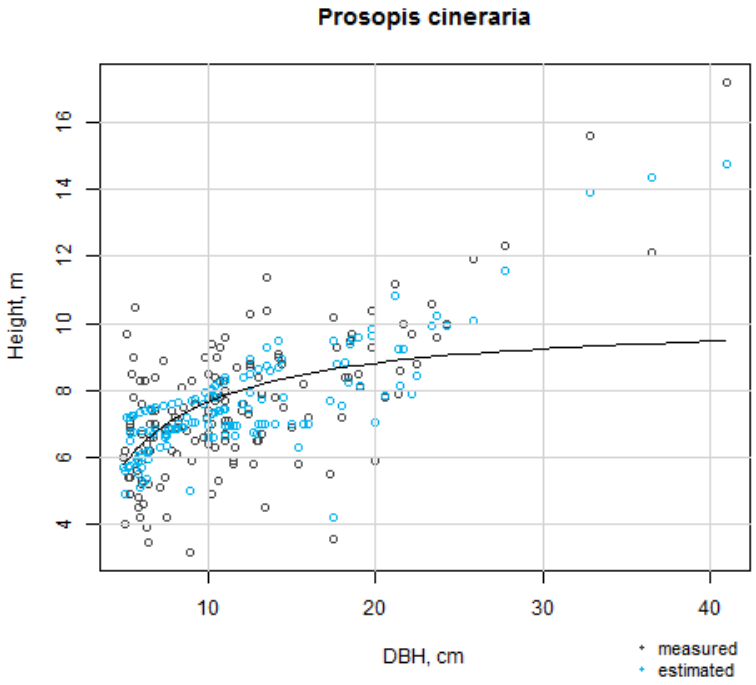


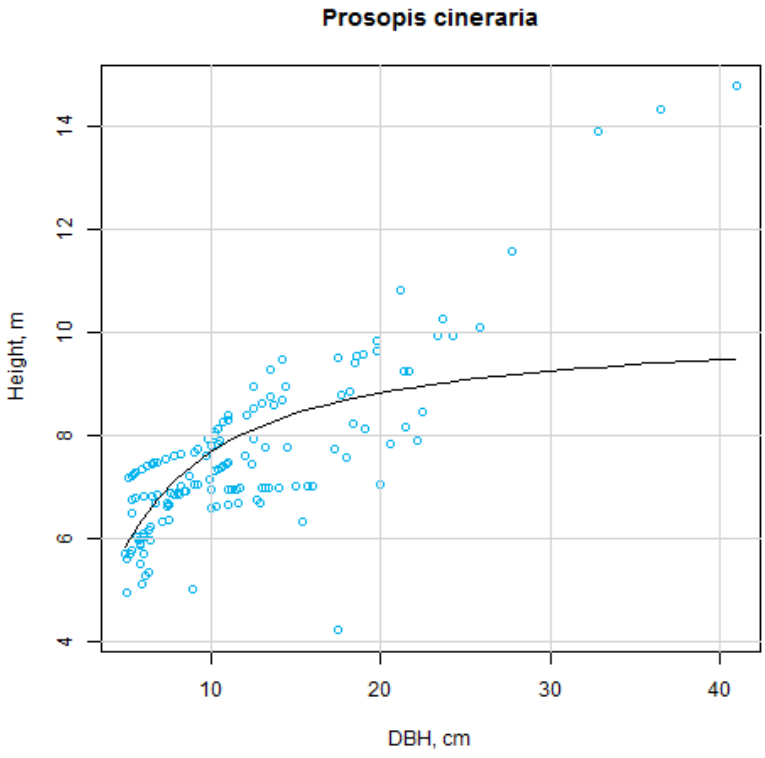
Prosopis spp.

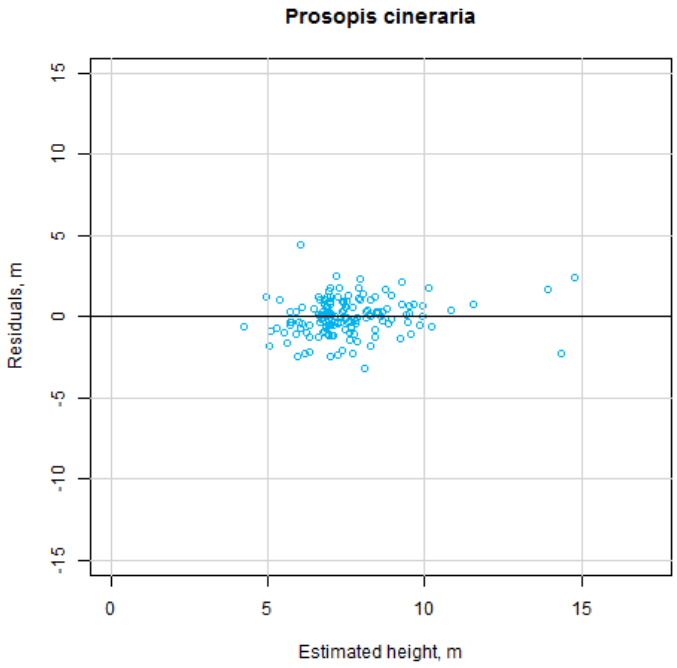
Plot id (cluster00000plot)	a	b
608000005	0.904756	0.860055
2123000005	2.819211	2.662184
2173000002	-3.26811	-2.83187
2173000004	8.647008	7.495822
2173000005	1.58223	1.146943
2497000003	-5.83933	-5.20397
2497000005	-3.85853	-3.37273
2549000001	-0.57515	-0.01846
2549000002	-1.65922	-2.27913
2549000003	2.518118	2.436607
2549000004	-2.76041	-1.87687
2549000005	-3.03461	-2.97834
2606000002	-1.3588	-1.17231
2606000003	-6.2874	-5.53692
2922000001	4.379857	4.108432

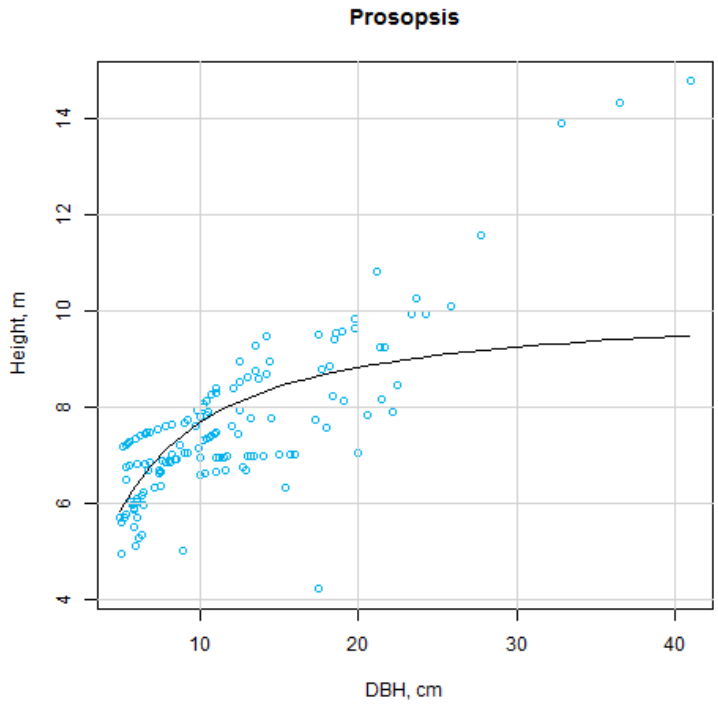
10505000004	1.242525	0.885971
26271000001	0.281076	0.240335
26271000002	4.478115	3.678211
26271000004	4.245324	3.494232
26271000005	0.992245	0.837052
191832000001	1.659409	1.529226
191832000002	0.871717	1.093277
191832000003	-1.69258	-1.39249
191832000004	-2.06296	-1.80309
191832000005	-2.2245	-2.00217

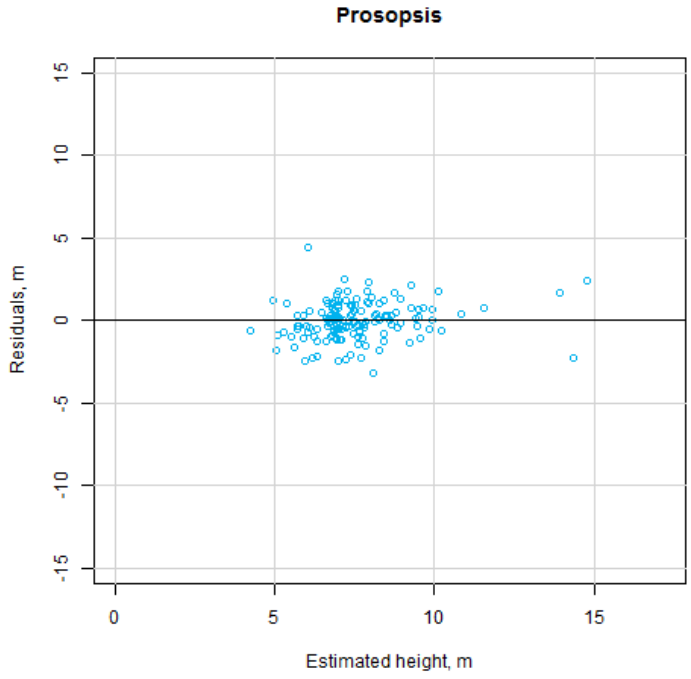



Prosopis cineraria
Height, m
4
6
8
10
12
14
16
10
20
30
40
DBH, cm
measured
estimated


Prosopis cineraria
Height, m
4
6
8
10
12
14
10
20
30
40
DBH, cm


Prosopis cineraria
Residuals, m
15
10
5
0
-5
-10
-15
0
5
10
15
Estimated height, m


Prosopsis
Height, m
4
6
8
10
12
14
10
20
30
40
DBH, cm

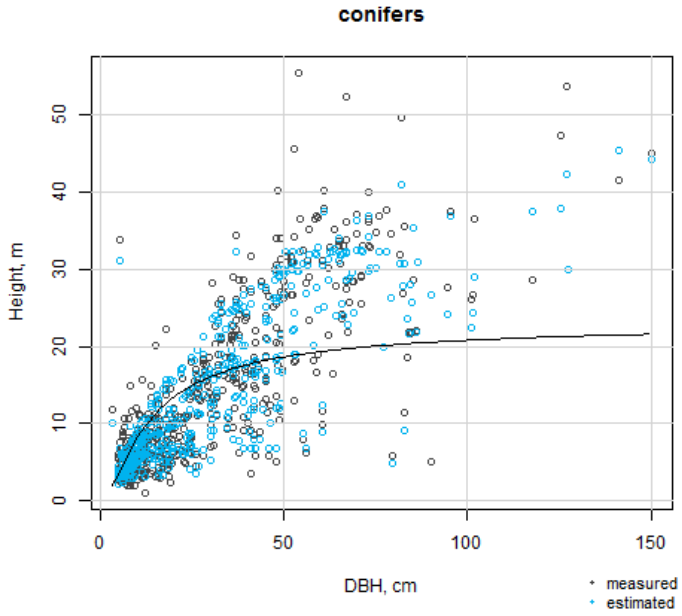

Prosopsis
Residuals, m
-15
-10
-5
0
5
10
15
0
5
10
15
Estimated height, m

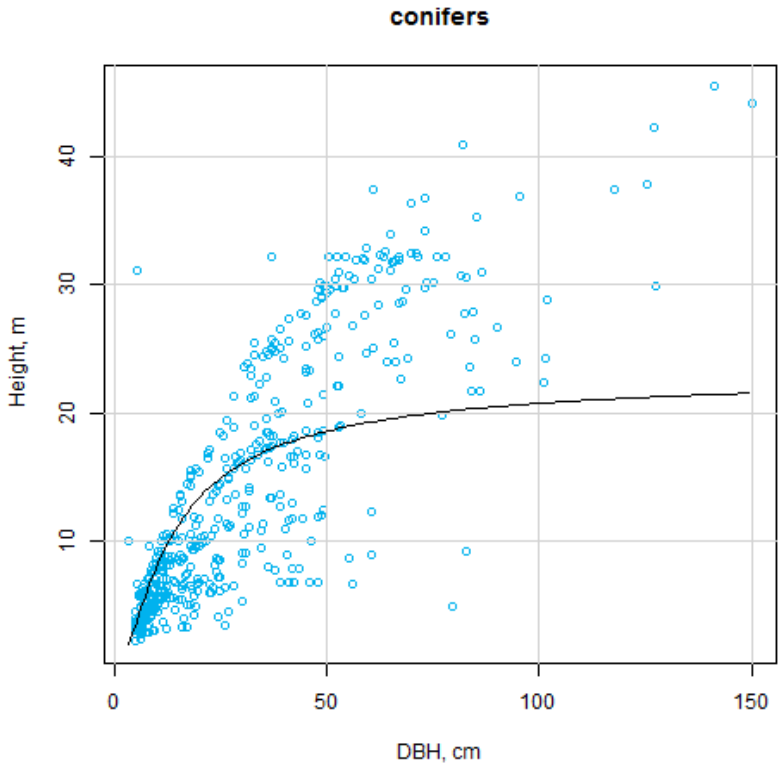
Conifer species

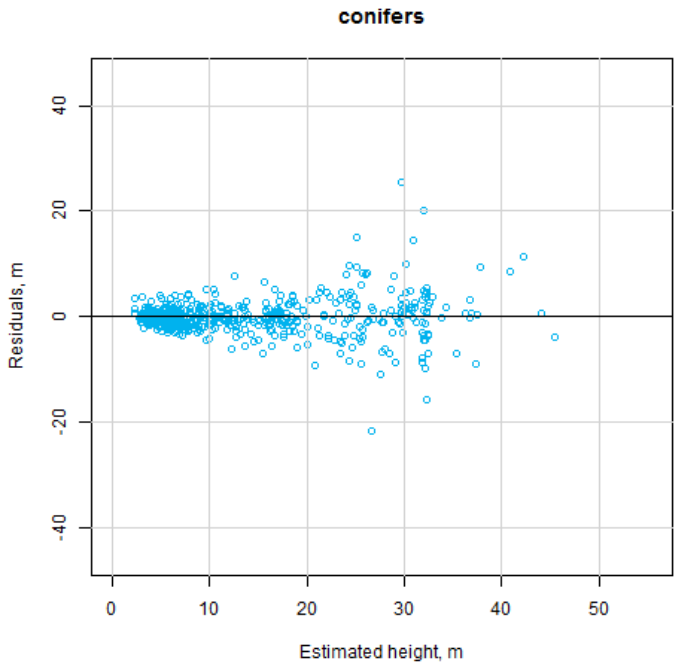
Plot id cluster00000plot	*a*	*b*
344000001	7.061384	0.197306
344000003	9.760289	10.269540
344000004	14.797233	5.129694
344000005	32.420400	23.885866
427000001	-2.719136	-0.748998
427000002	9.093897	-11.687812
427000003	6.264850	-0.586567
427000004	25.912526	9.916924
427000005	22.335139	8.070213
444000001	14.066476	6.609711
444000002	14.967256	7.114023
444000003	24.126407	12.855329
444000004	19.210361	7.548876
444000005	19.933374	8.980417
460000001	6.494936	2.104712
460000002	4.298330	1.135006
460000003	-5.795552	-4.150656
460000004	22.893414	10.602508
460000005	24.420776	11.762269
486000003	-2.413214	-4.685507
486000004	-6.788142	-0.247071
486000005	2.806535	0.862041
488000002	10.796450	5.453150
488000003	29.424798	9.504096
488000004	17.919301	7.005182
494000001	-1.917274	-0.367969
494000004	-2.043818	0.848985
494000005	-10.929334	-2.547060

510000001	-2.989303	-1.323111
510000003	-9.469261	-4.487752
510000005	-5.755720	-9.792330
511000001	-0.248852	-0.111245
535000002	-7.335132	-3.052956
535000004	16.874826	9.811654
535000005	15.917897	10.279198
701000001	-2.435604	0.913938
701000002	-7.014850	-1.514570
701000003	-10.888456	-6.681638
701000004	-13.014716	-5.655976
701000005	-11.153186	-2.264545
1151000001	-14.342153	-5.879749
1151000002	-15.846164	-7.708754
1151000003	-13.449485	-3.115374
1151000004	-13.521960	-5.123966
1151000005	-13.269515	-4.150970
1196000002	-15.117232	-6.316150
1196000003	-17.279731	-7.397653
1196000005	-12.233387	-5.192251
5839000001	2.674630	3.931439
5839000002	20.314972	6.525050
5839000003	4.566205	2.488215
5839000004	-8.755247	-3.929411
7057000001	0.325642	0.224584
7057000004	-2.673930	-2.568460
7057000005	-1.199339	-0.665971
7864000001	-5.612121	-0.950229
7864000002	-3.279813	-0.268075
7864000003	5.706239	0.677360
7864000005	15.295527	7.172823
9291000001	1.601335	0.334490

9291000002	-0.164929	-0.746888
9291000004	-1.516714	-0.555806
9291000005	17.486502	5.537843
15916000005	-15.604913	-6.571296
16115000001	-15.952350	-6.374962
16115000003	-14.283945	-5.534830
16115000004	-18.680680	-8.460990
16115000005	-8.174673	-2.006126
16315000001	-14.071573	-5.237762
16315000002	-11.578212	-3.257785
16315000003	-18.114343	-7.083197
16315000004	-17.156170	-7.854427
16315000005	-19.402714	-8.373398
16323000001	-13.068162	-4.767553
16323000004	-16.250605	-10.631747
16323000005	-16.256301	-7.122900


conifers
Height, m
0
10
20
30
40
50
0
50
100
150
DBH, cm
measured
estimated


conifers
Height, m
10
20
30
40
0
50
100
150
DBH, cm



d = diameter at breast height

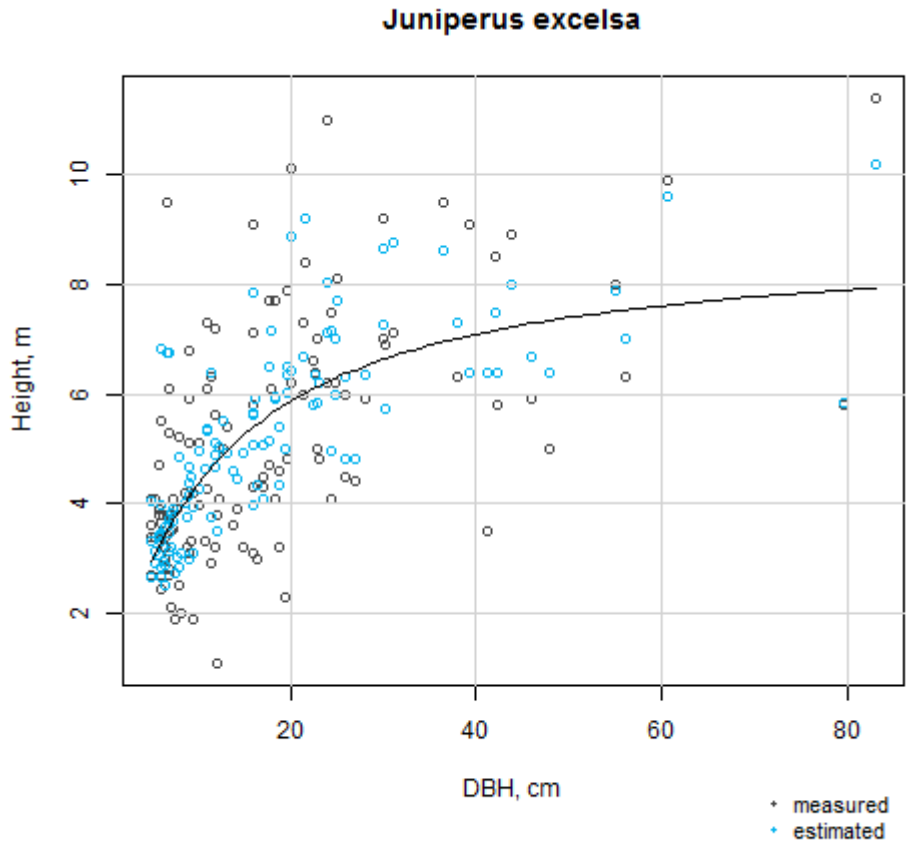
h = tree height

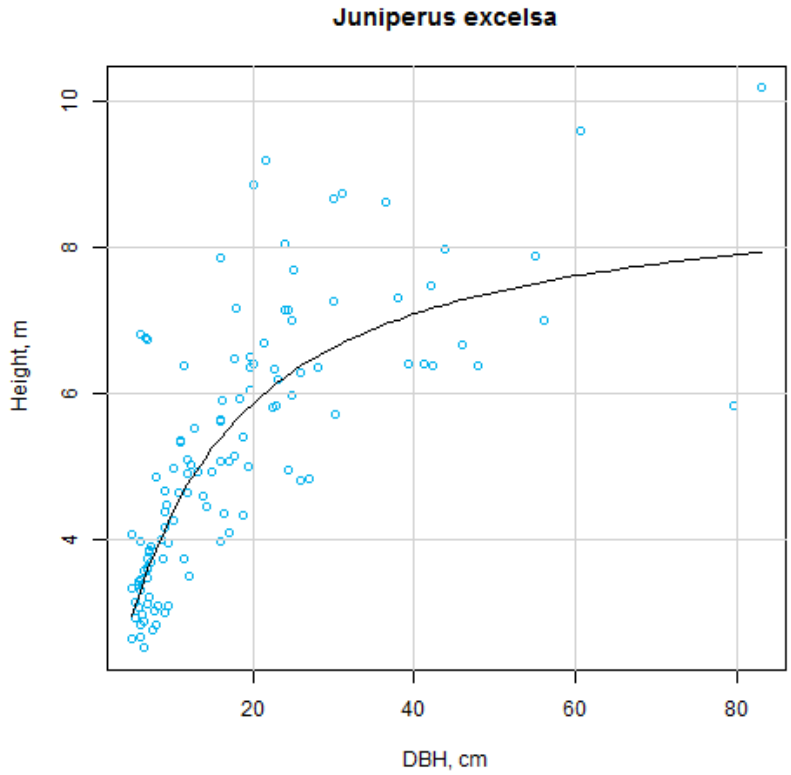
h = d^2/(a+b*d)^2 (Näslund model)

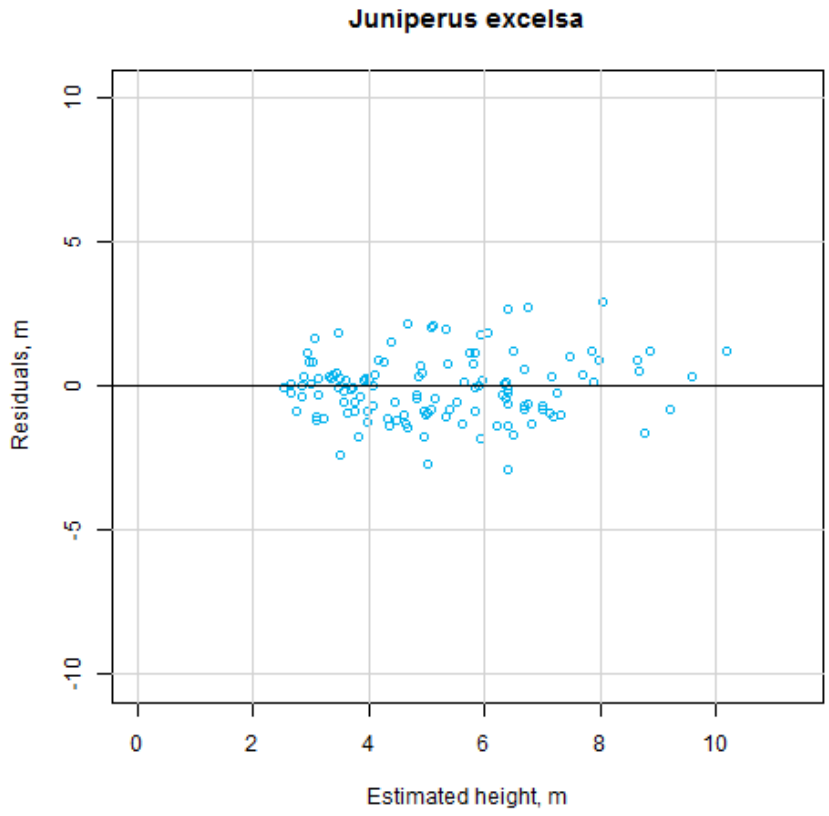
Juniperus excelsa

Plot id cluster00000plot	a	b
1151000001	-0.308004	-0.017672
1151000002	-1.164153	0.048196
1151000003	1.134695	-0.083354
1151000004	-0.127669	-0.009194
1151000005	0.543142	-0.060162
1196000002	-0.228449	-0.000590
1196000003	0.293721	0.033968
1196000005	-0.129838	-0.061513
15916000005	0.305719	0.016465
16115000001	-0.159960	0.021803
16115000003	0.066525	-0.012641

16115000004	0.432433	0.058003
16115000005	0.047218	-0.109213
16315000001	-0.074646	-0.009688
16315000002	0.235480	-0.062196
16315000003	0.513005	0.075014
16315000004	-0.402406	0.051950
16315000005	1.216023	0.045111
16323000001	-0.045160	-0.022312
16323000004	-2.273364	0.084691
16323000005	0.125690	0.013332

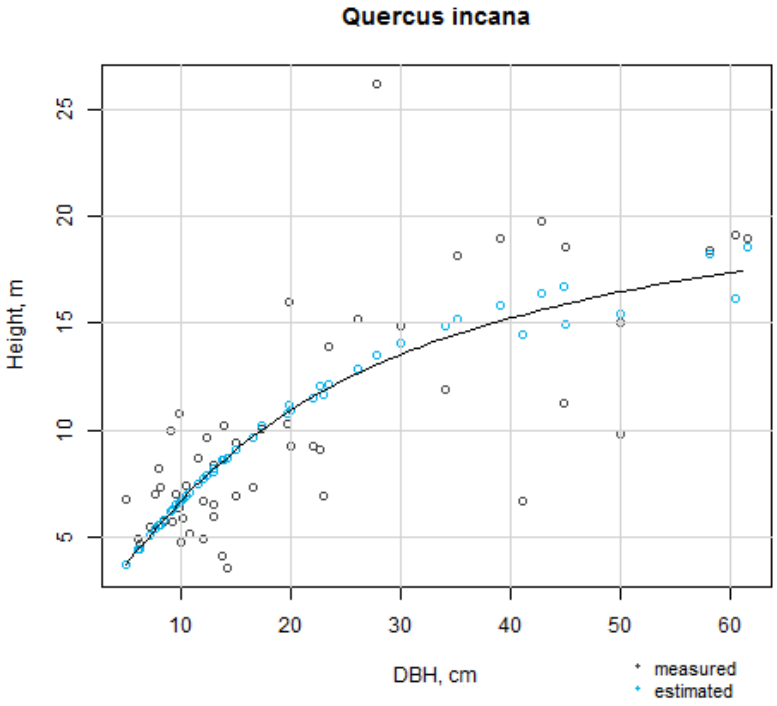


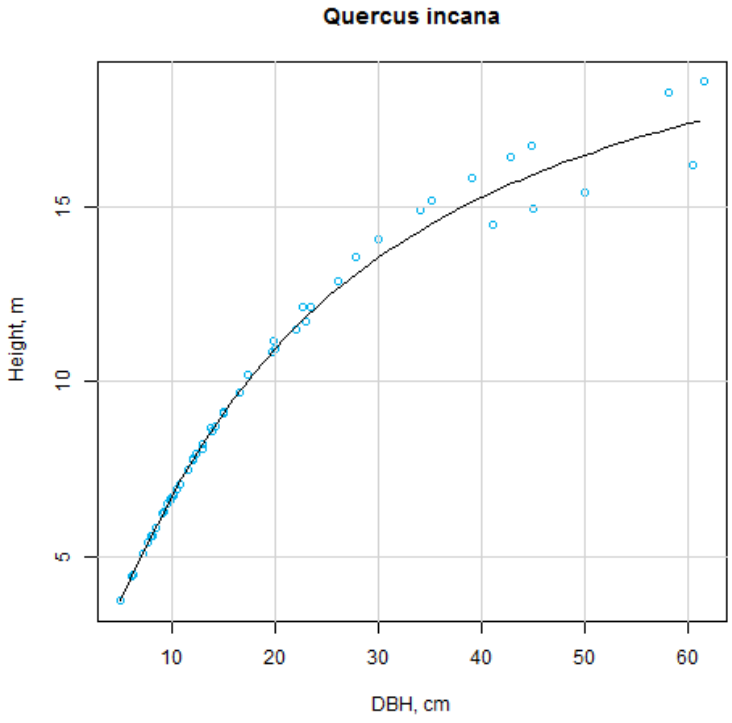

Juniperus excelsa
Height, m
DBH, cm
4
6
8
10
20
40
60
80

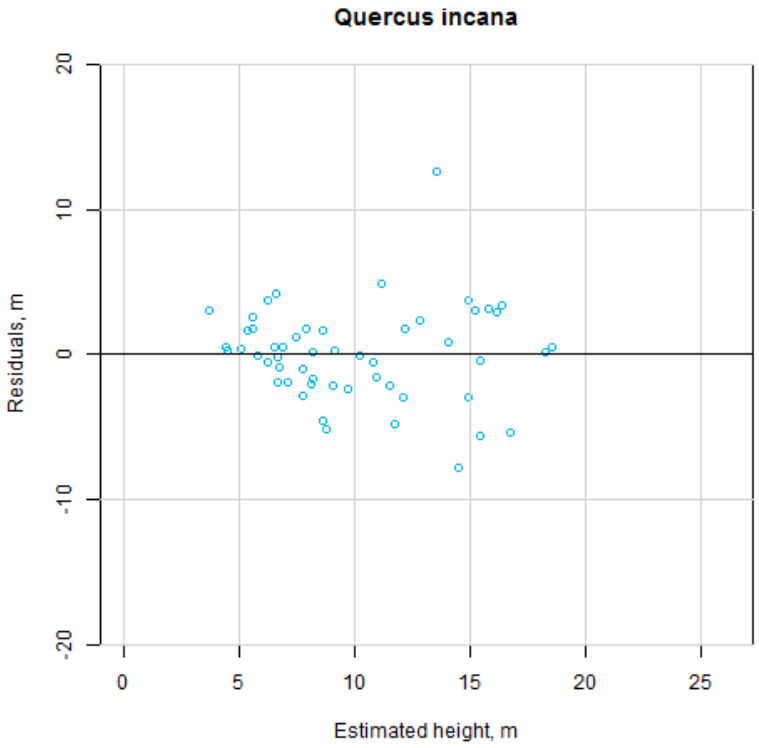

Juniperus excelsa
Residuals, m
Estimated height, m
-10
-5
0
5
10
0
2
4
6
8
10

Quercus incana

Plot id cluster00000plot	a	b
427000001	-0.010741	0.001003
427000002	-0.041730	0.003893
427000004	-0.006080	0.000567
427000005	0.044258	-0.004122
460000002	-0.002349	0.000211
460000003	-0.000527	0.000051
486000004	-0.017799	0.001661
494000001	-0.131238	0.012214
494000004	0.103261	-0.009631
494000005	0.097326	-0.009064
519000005	-0.018081	0.001682
701000001	-0.012147	0.001141
701000002	-0.002495	0.000238
701000003	-0.002558	0.000235
701000005	0.000899	-0.000080


Quercus incana
Height, m
5
10
15
20
25
10
20
30
40
50
60
DBH, cm
measured
estimated

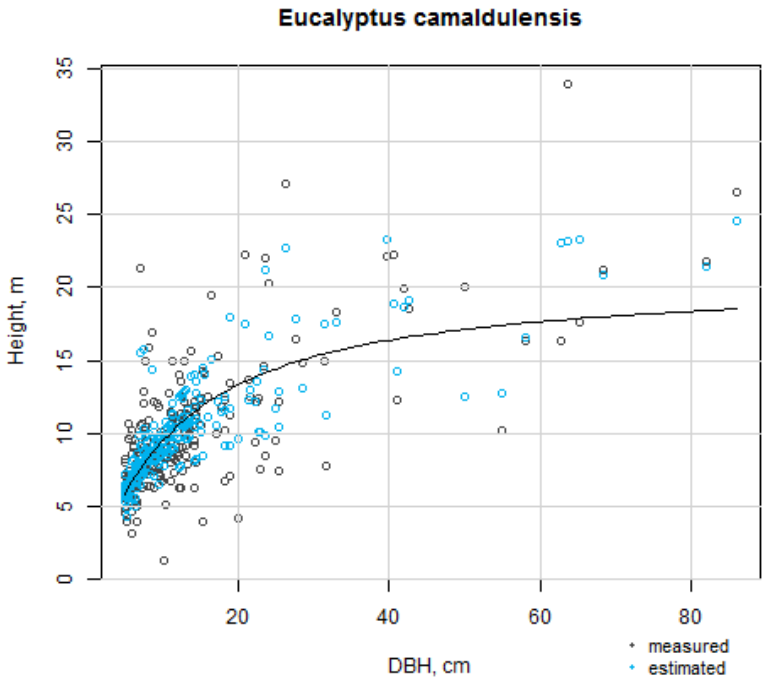

Quercus incana
Height, m
5
10
15
10
20
30
40
50
60
DBH, cm

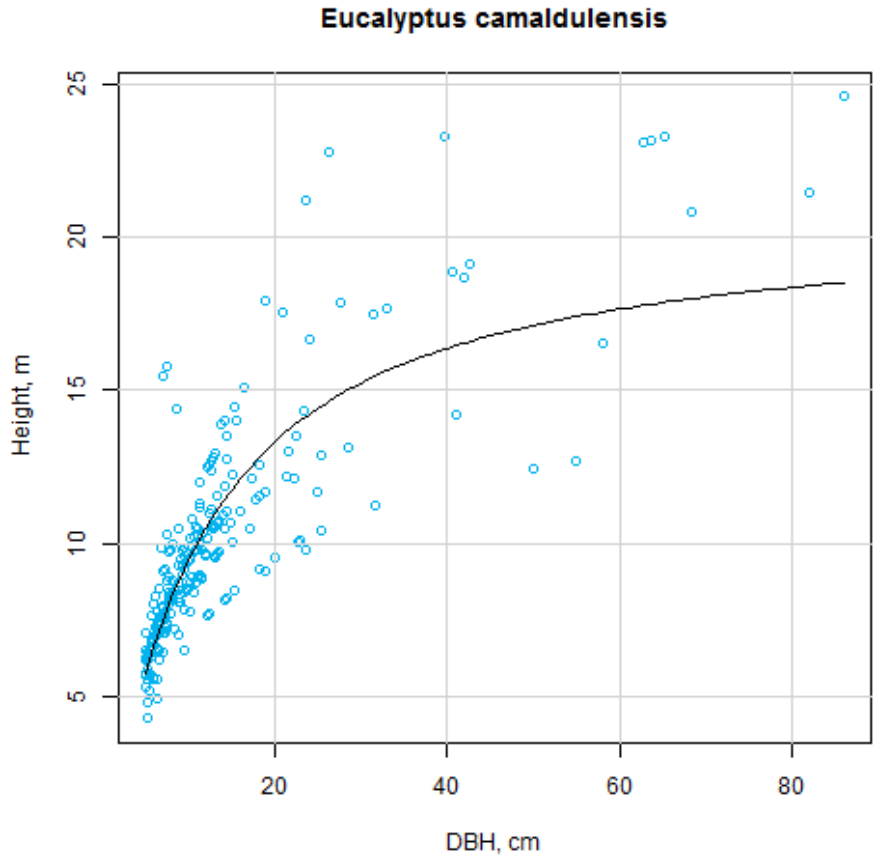


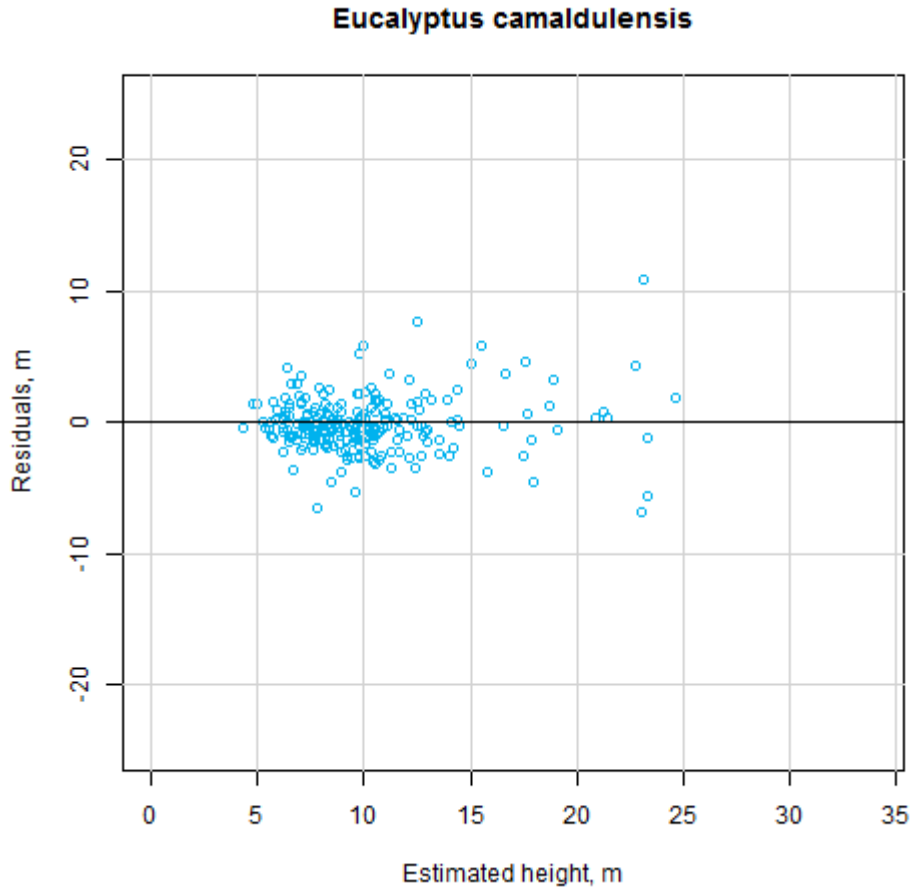
Eucalyptus spp.

Plot id cluster00000plot	a	b
486000002	-0.735662	-0.009698
757000001	0.426226	-0.026350
855000001	0.099827	0.009786
855000005	-0.206058	0.042567
1124000002	0.154984	0.057560
1124000003	0.241748	0.007674
2549000001	0.001499	0.003666
2549000004	0.110603	0.017274
11311000001	-0.212934	-0.012339
11311000002	-0.435831	-0.000734

11311000003	-0.419699	0.011494
11311000004	0.268978	0.019600
11311000005	0.346185	-0.053244
11743000002	0.120982	-0.020691
11923000001	-0.150730	-0.024610
11923000002	0.526077	-0.045078
11923000005	-0.013547	0.009076
13925000001	-0.054437	0.020935
13925000002	-0.150005	0.056657
13925000004	0.072911	-0.005980
15567000001	-0.118998	0.003673
15567000002	-0.019894	0.003829
15567000003	0.196752	-0.023502
15567000004	-0.092454	-0.000603
15567000005	-0.230774	0.026539
15973000001	-0.300758	0.029024
15973000002	-0.002115	-0.005904
15973000004	-0.153056	0.015835
15973000005	0.074819	0.006276
18605000002	0.319301	-0.052807
58372000001	0.768082	-0.087710
58372000003	-0.052430	0.009023
58372000005	0.079185	0.001010
76186000002	0.400351	0.040189
76186000003	-0.936982	-0.004810
235062000002	-0.486965	0.033699
235062000003	-0.179041	-0.001632
235062000004	0.074407	0.011075
315476000002	0.123215	-0.001442
315476000004	0.130523	-0.020555
315476000005	0.415715	-0.038773


Eucalyptus camaldulensis
Height, m
0
5
10
15
20
25
30
35
20
40
60
80
DBH, cm
measured
estimated


Eucalyptus camaldulensis
Height, m
5
10
15
20
25
20
40
60
80
DBH, cm

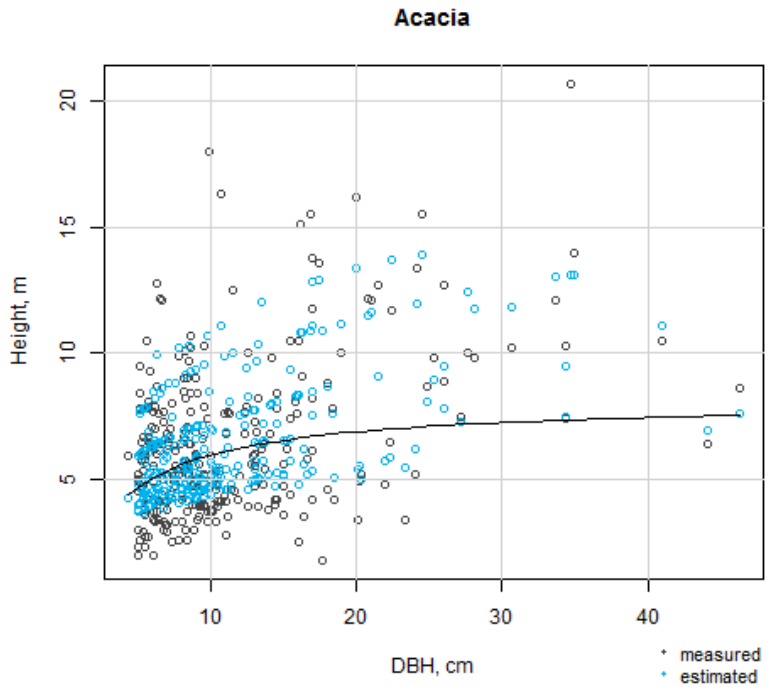


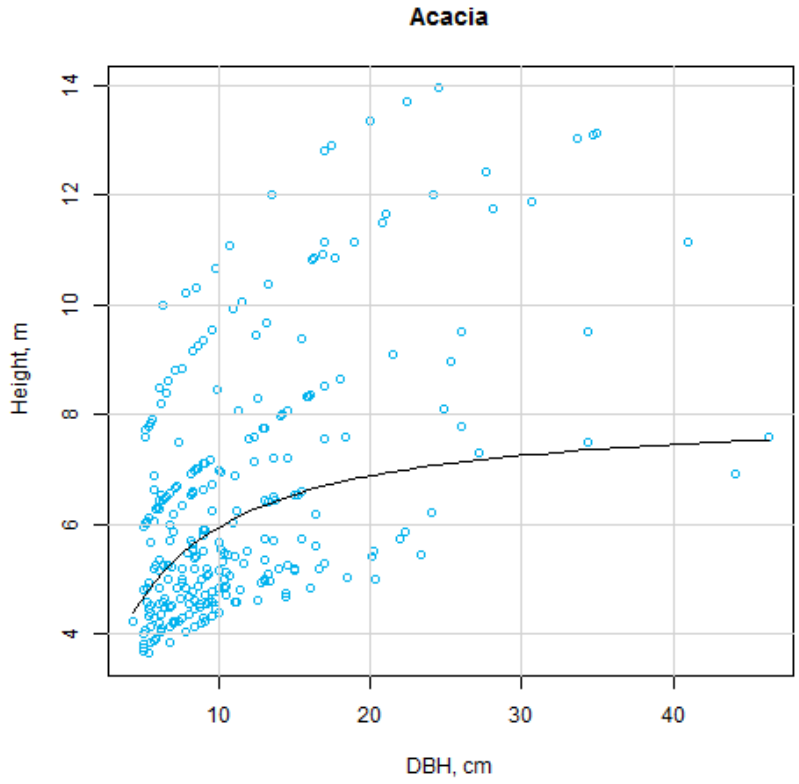
Acacia spp.

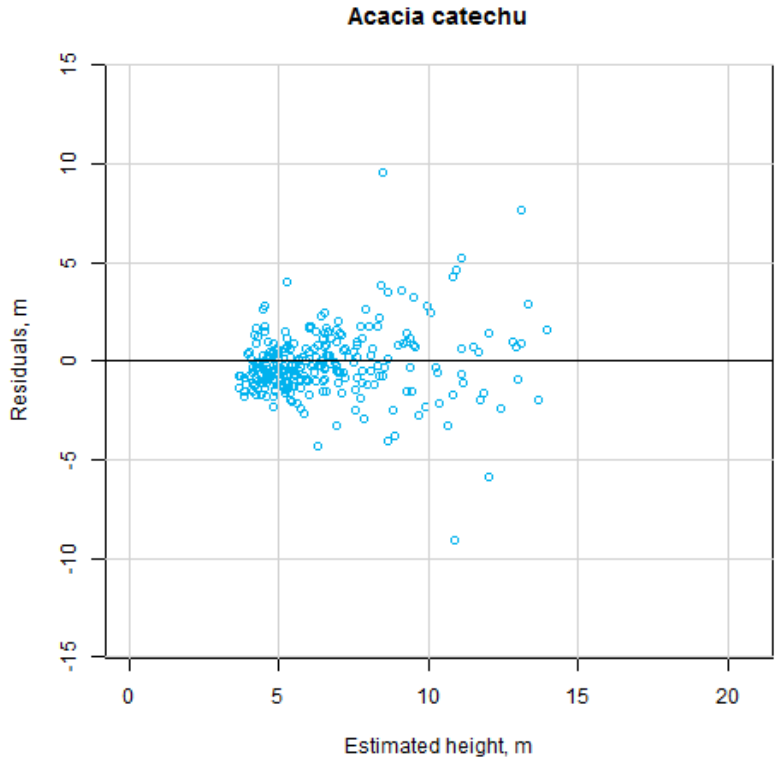
Plot id cluster00000plot	a	b
485000002	-0.032786	-0.025461
485000003	-0.020264	-0.054058
538000001	0.028579	0.012428
538000002	-0.002602	-0.000601
538000004	0.061340	-0.024109
538000005	0.069017	0.030894
639000003	0.032994	0.012335
639000005	0.089558	0.036128
887000001	0.251596	0.089303
887000002	0.058484	0.032997
887000004	0.192878	0.066360

887000005	0.251922	0.057325
929000001	0.042892	0.018925
929000002	0.155526	0.085183
929000003	0.043233	0.028034
929000004	0.043049	0.037535
929000005	0.168023	0.091266
2123000001	-0.012908	-0.032351
2123000002	-0.089753	-0.108099
2123000005	-0.080736	-0.133186
2549000001	0.022363	0.001553
2549000005	-0.146256	-0.020581
2616000004	0.019882	0.019199
2852000001	0.088436	0.060619
2852000002	-0.002716	0.021169
2852000003	-0.003551	-0.058181
2852000004	0.108755	0.060912
2852000005	0.063014	-0.003570
10505000001	-0.084606	0.011279
10505000002	0.038352	0.011239
10505000003	0.075105	0.029928
10505000004	0.121039	0.039411
10505000005	0.004071	0.014732
11743000003	-0.090019	-0.078489
16141000002	0.117543	0.034951
16141000003	0.014993	0.034093
16141000005	0.063849	0.031962
16145000001	0.082359	0.046059
16145000002	0.161425	0.067763
16145000004	-0.033675	-0.001849
16145000005	0.014383	0.070160
17562000001	0.099534	0.023753
17562000002	0.011835	0.028239

17562000004	0.132799	0.065297
17562000005	0.075672	0.052827
18605000001	0.338437	-0.126342
18605000002	-0.665539	-0.068685
18605000003	-0.076937	-0.063949
18605000004	-0.178147	-0.024742
18605000005	-0.168076	-0.021566
19011000005	-0.002328	-0.004600
27269000004	0.010555	0.003463
76186000001	0.349957	-0.079447
76186000002	-0.206157	-0.045188
76186000003	-0.365224	-0.082352
76186000004	-0.259022	-0.029494
76186000005	-0.253023	-0.094879
235062000002	-0.258992	-0.058006
235062000003	-0.223471	-0.038174
235062000004	-0.246662	-0.049359

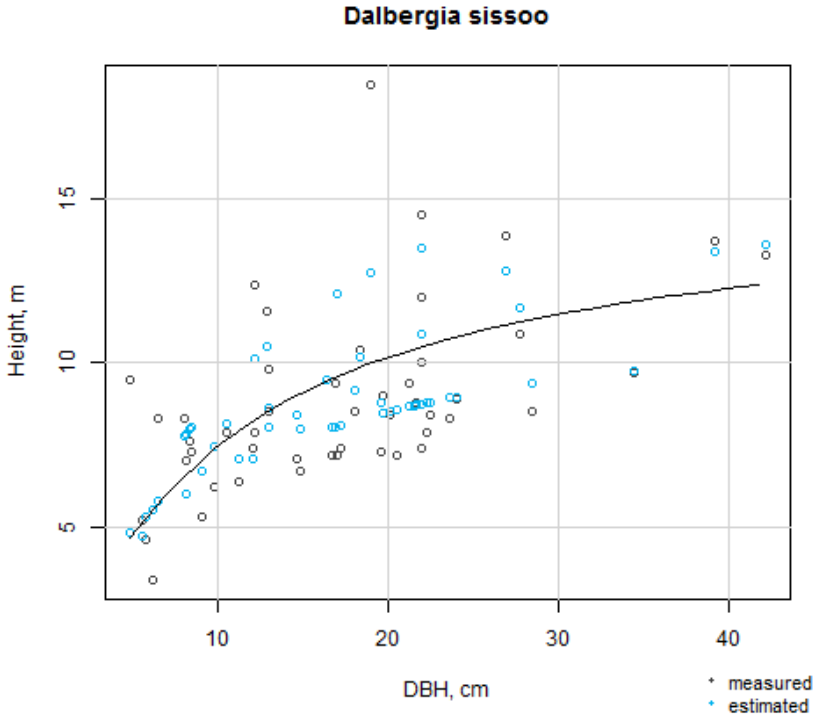

Acacia
Height, m
5
10
15
20
10
20
30
40
DBH, cm
measured
estimated

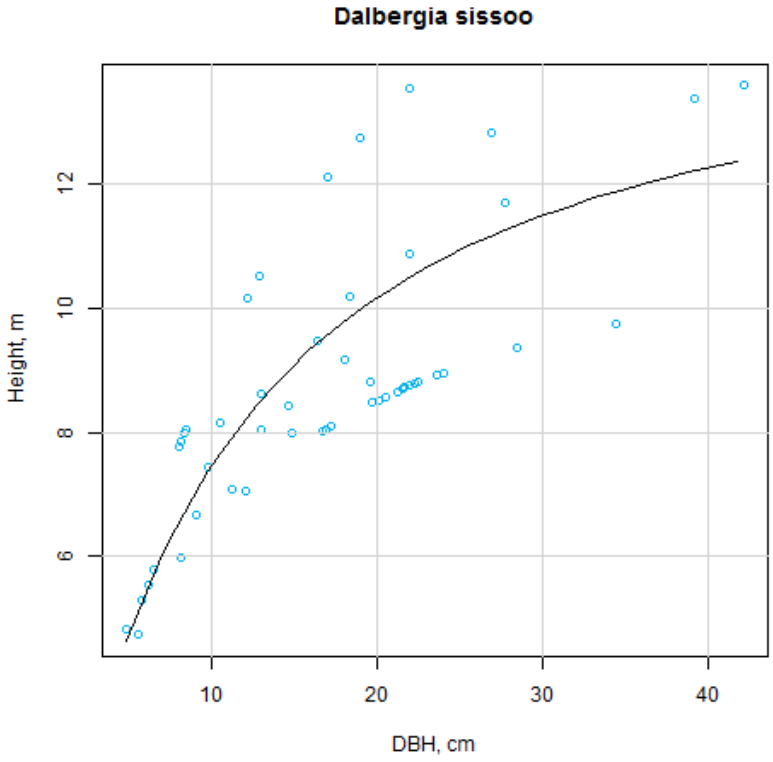

Acacia
Height, m
4
6
8
10
12
14
10
20
30
40
DBH, cm

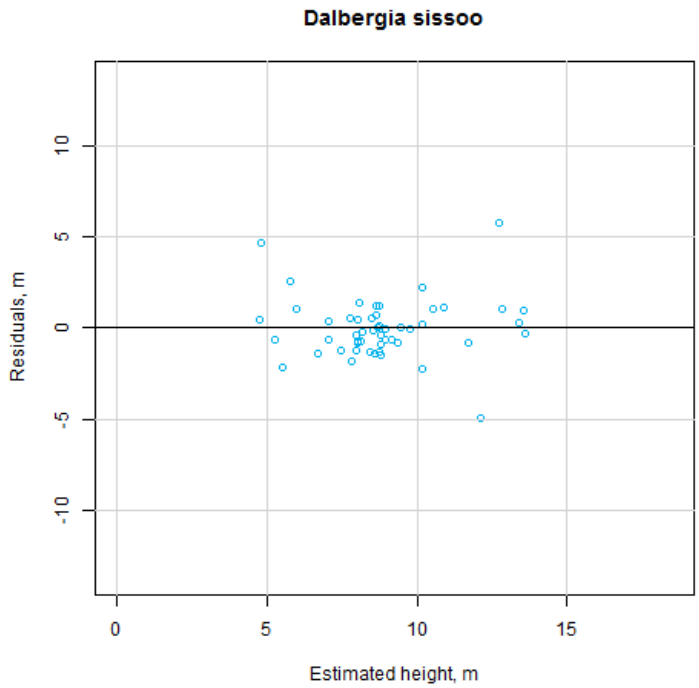


Dalbergia Sissoo

Plot id	a	b
485	-0.000001	-0.044122
535	0.000000	0.014258
536	0.000000	0.013505
855	0.000000	-0.000494
1124	0.000001	0.028053
11743	0.000000	-0.006732
11923	0.000000	-0.015133
71691	0.000001	0.037127
76186	-0.000001	-0.024061
235062	0.000000	-0.002400

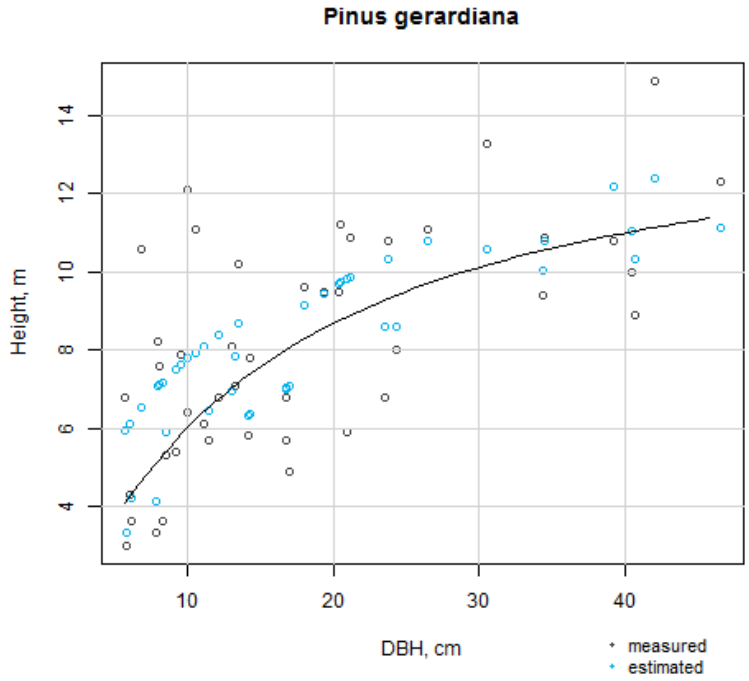

Dalbergia sissoo
Height, m
5
10
15
10
20
30
40
DBH, cm
measured
estimated

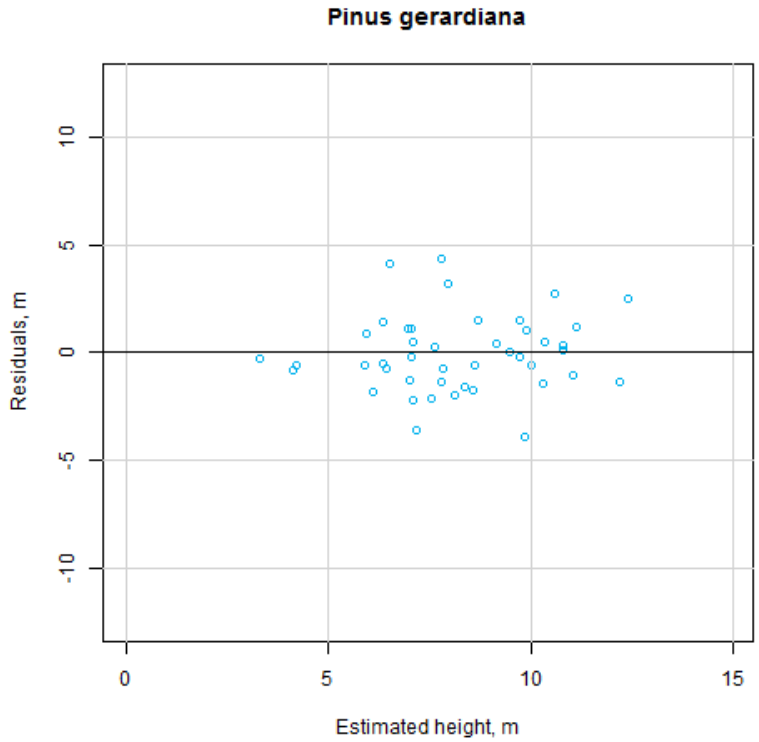

Dalbergia sissoo
Height, m
6
8
10
12
10
20
30
40
DBH, cm

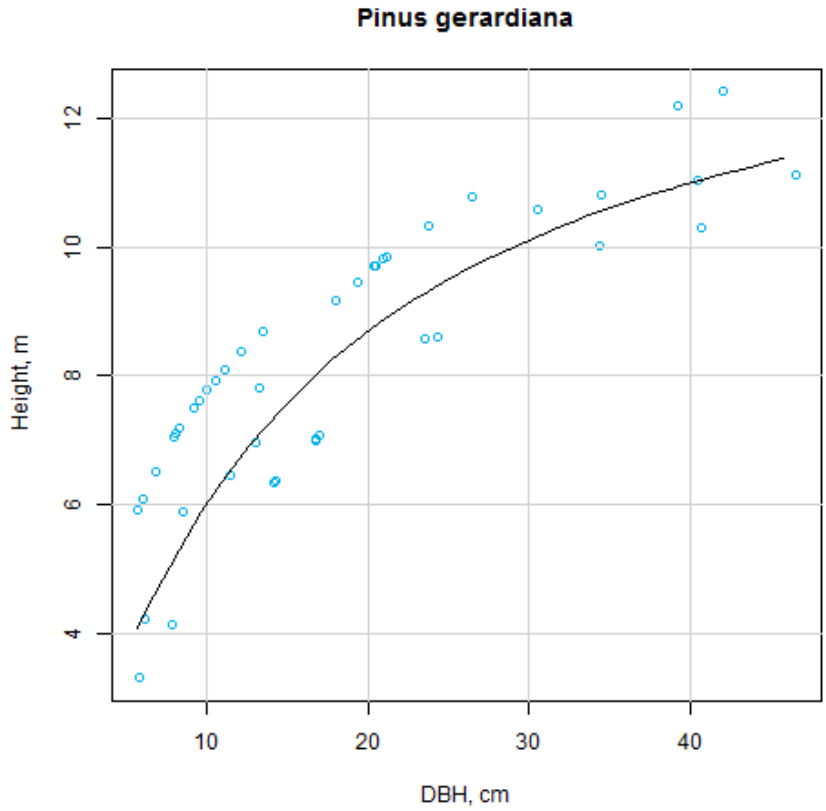


Pinus gerardiana

Plot id cluster00000plot	a	b
701000001	0.054049	-0.001932
701000002	-0.090518	-0.016856
701000003	-0.919815	0.022408
701000004	0.219871	0.007588
701000005	0.736414	-0.011208

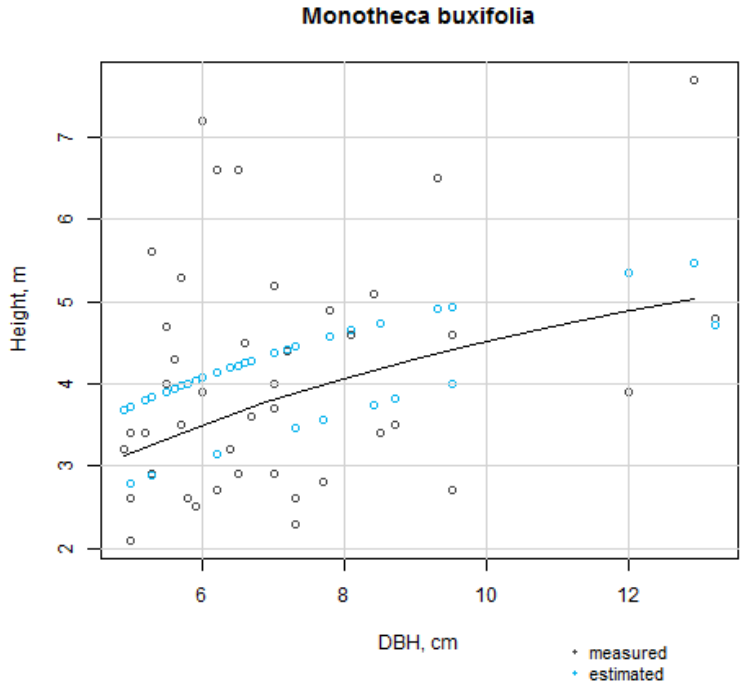

Pinus gerardiana
Height, m
4
6
8
10
12
14
10
20
30
40
DBH, cm
measured
estimated

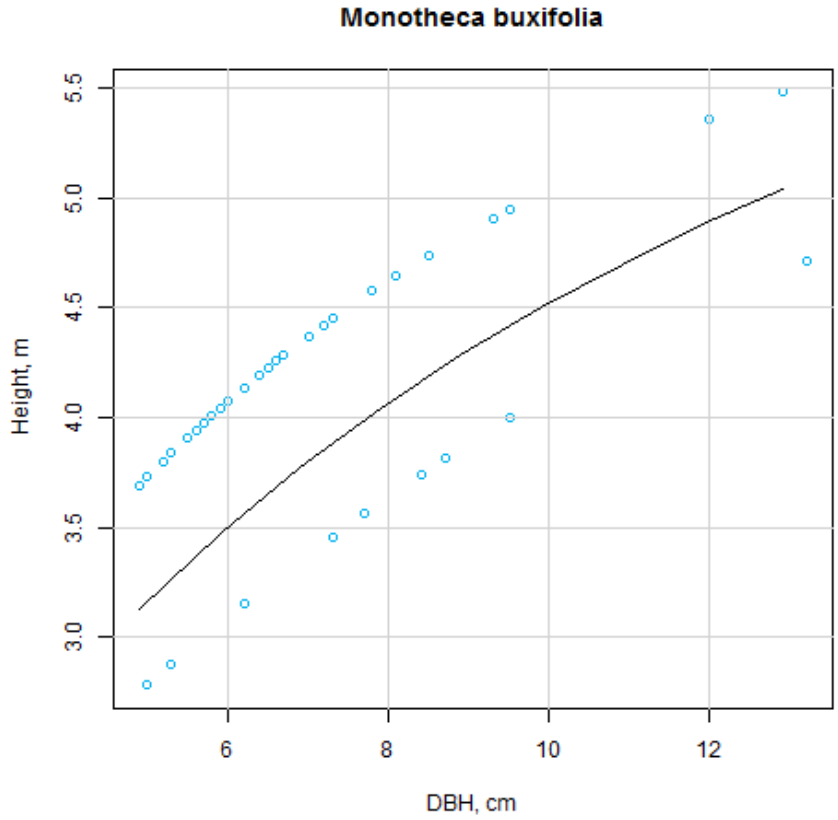

Pinus gerardiana
Residuals, m
-10
-5
0
5
10
0
5
10
15
Estimated height, m

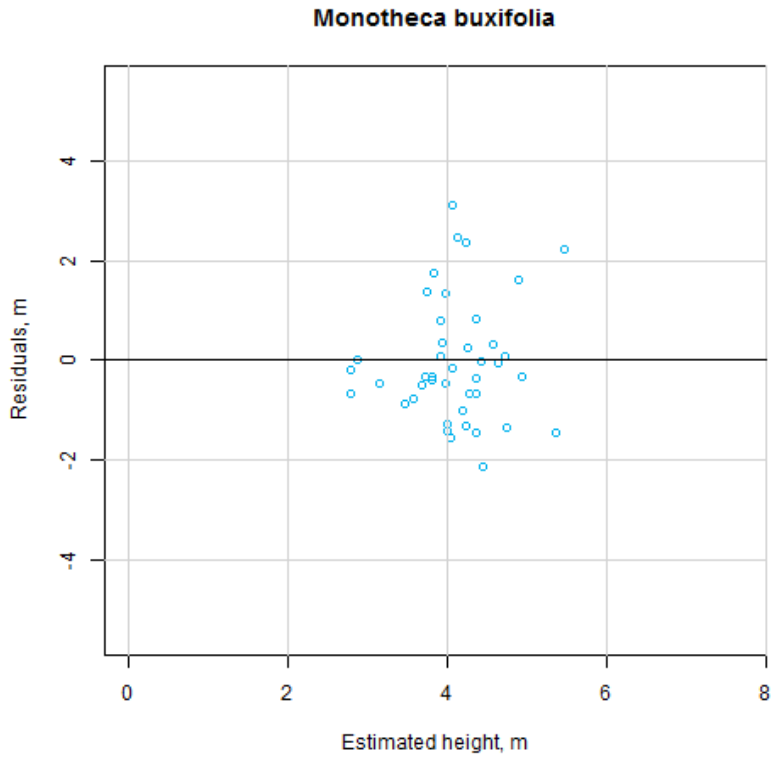


Monotheca buxifolia

Cluster id	a	b
538	-0.53883	0.012907
887	0.538833	-0.01291

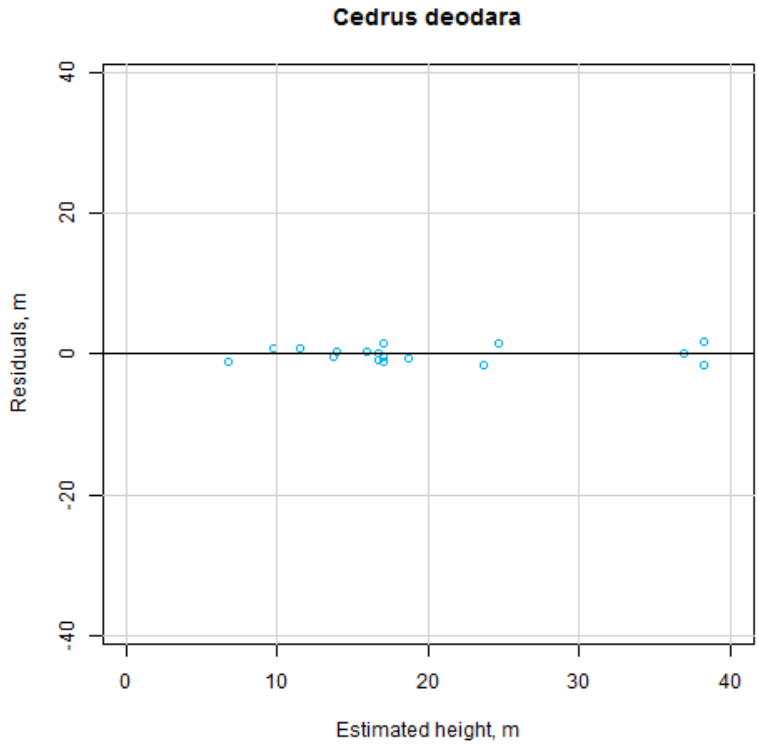

Monotheca buxifolia
Height, m
DBH, cm
measured
estimated

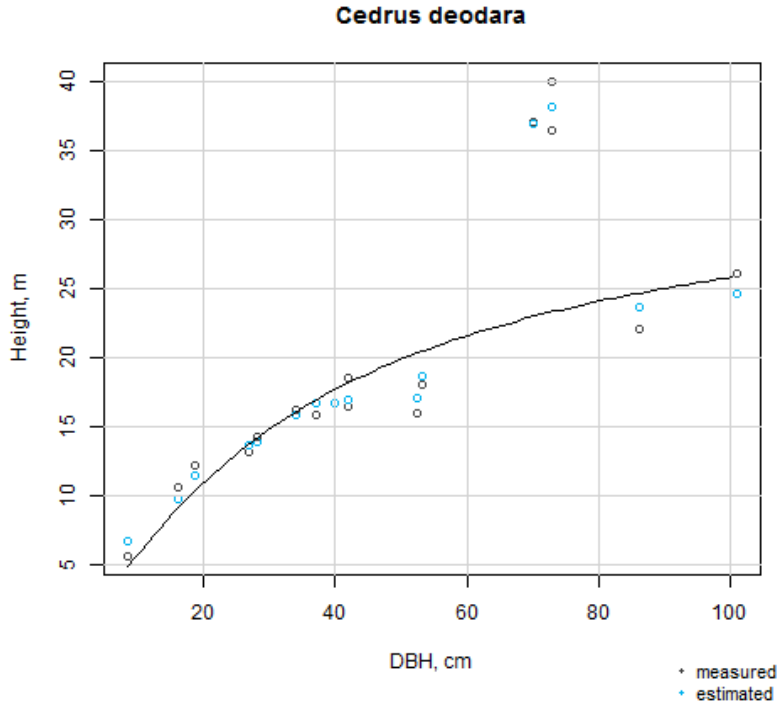

Monotheca buxifolia
Height, m
DBH, cm

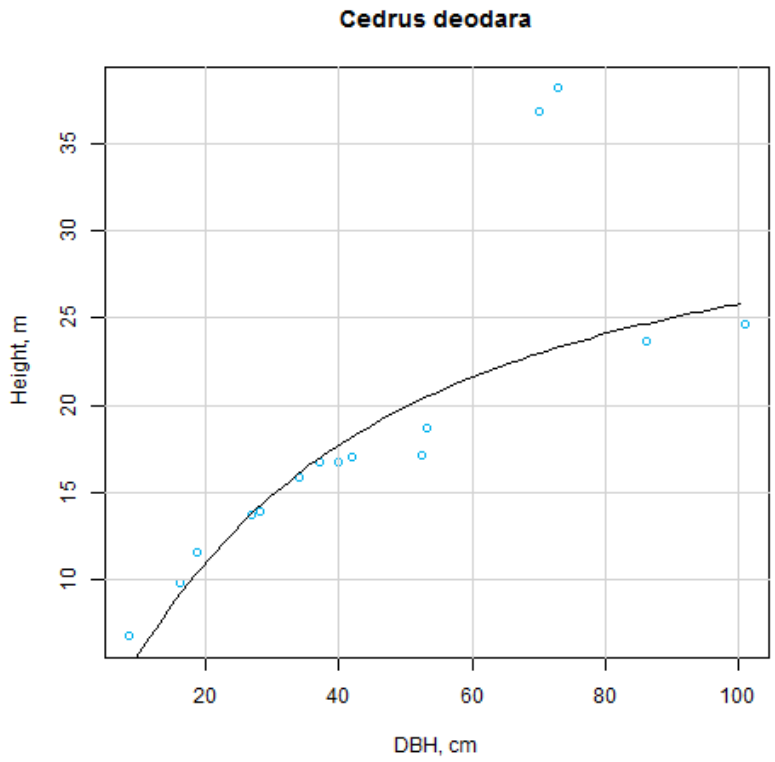


Cedrus deodara

Cluster id	a	b
427	2.018604	-0.07635
5839	-0.18213	0.006891
7057	-0.62474	0.023625
7864	-1.21174	0.04583

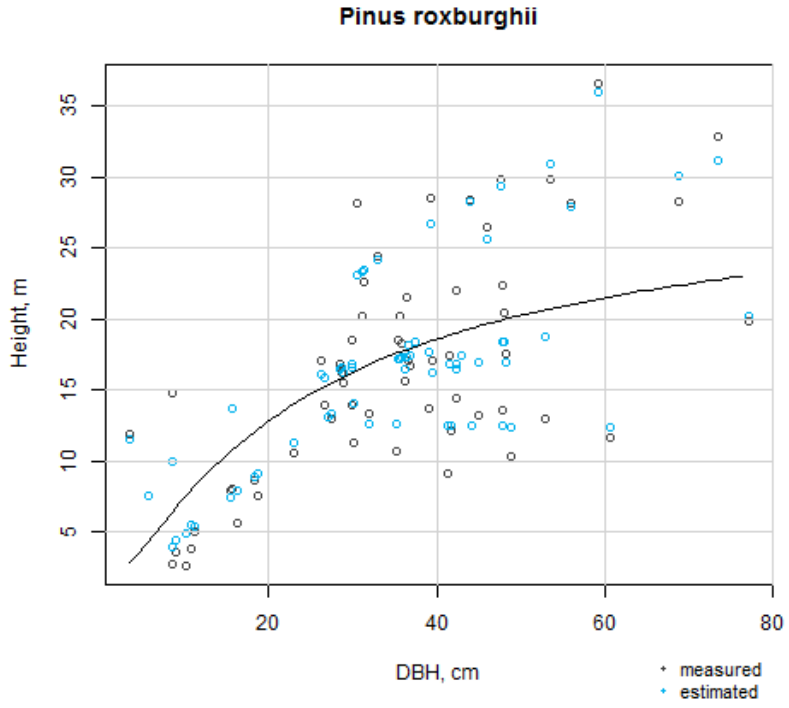

Cedrus deodara
Residuals, m
40
20
0
-20
-40
0
10
20
30
40
Estimated height, m

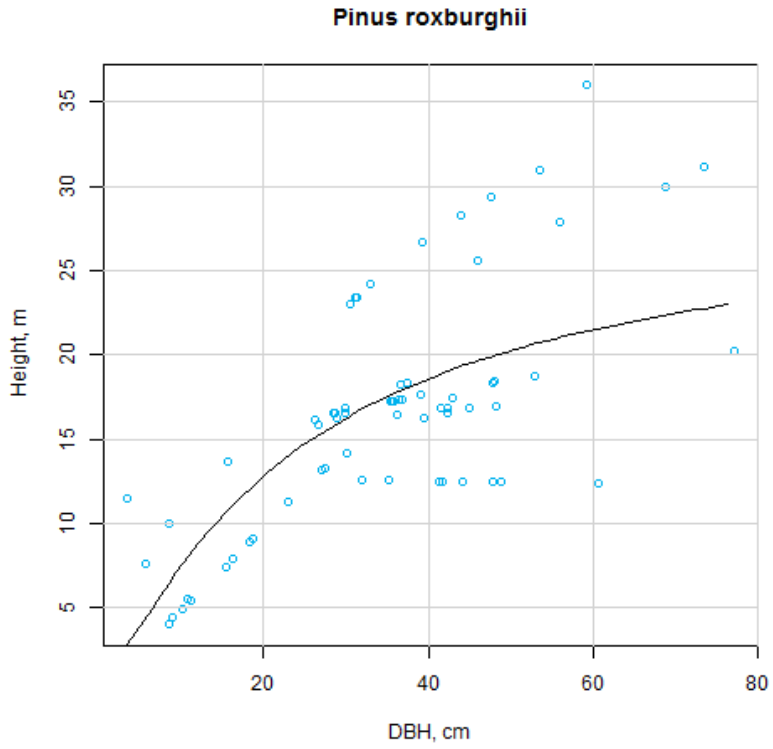

Cedrus deodara
Height, m
5
10
15
20
25
30
35
40
20
40
60
80
100
DBH, cm
measured
estimated

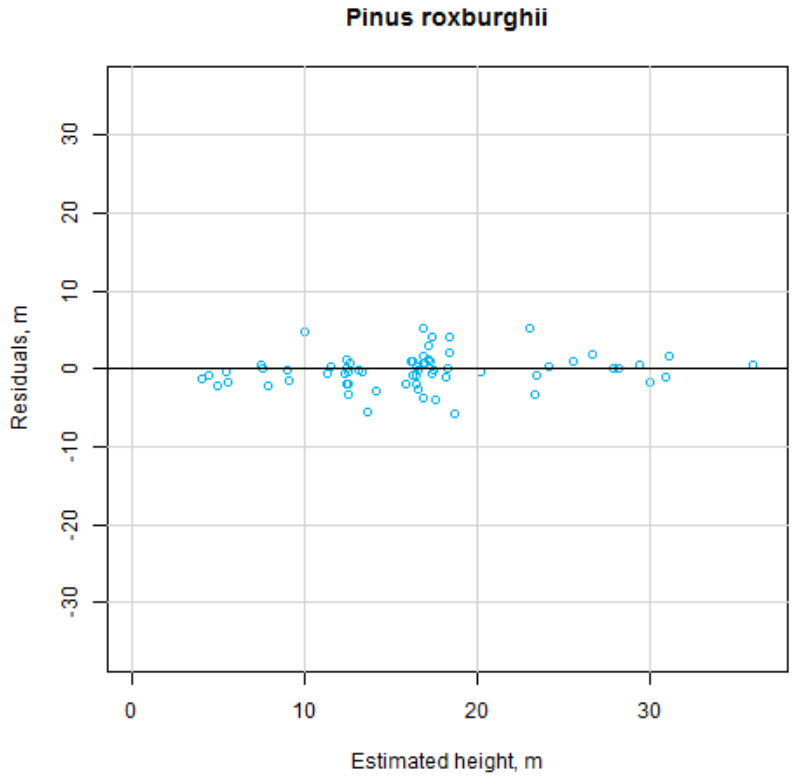

Cedrus deodara
Height, m
10
15
20
25
30
35
20
40
60
80
100
DBH, cm

Pinus roxburghii

Plot id cluster00000plot	a	b
427000003	1.214606	-0.05718
427000005	2.043043	-0.08783
486000003	-1.17711	0.034908
486000004	1.893545	-0.04592
486000005	-0.25931	0.000198
510000001	-0.78236	0.037479
510000003	-2.40309	0.118548
510000005	-1.95178	0.062203
511000001	-0.5524	0.02271
535000002	0.008206	0.020598
535000004	1.720934	-0.05642
535000005	2.024345	-0.06744
9291000001	-0.48667	0.011081
9291000002	-0.97163	0.030617
9291000004	-0.33208	0.019921
9291000005	0.01176	-0.04347


Pinus roxburghii
Height, m
5
10
15
20
25
30
35
20
40
60
80
DBH, cm
measured
estimated


Pinus roxburghii
Height, m
5
10
15
20
25
30
35
20
40
60
80
DBH, cm



Deciduous spp.

Plot id cluster00000plot	a	b
427000001	-0.006383	-0.009021
427000002	0.008785	0.033771
427000004	0.042239	-0.019533
427000005	-0.149907	-0.057190
460000002	-0.479009	-0.031754
460000003	-0.001238	-0.004444
485000001	-0.542308	0.011739
485000002	-0.003662	-0.032505
485000003	-0.459888	-0.029676
485000004	-0.073763	-0.029326
485000005	0.111296	-0.062640
486000001	-0.343937	-0.023874
486000002	-0.275826	-0.011167

486000003	0.069042	-0.128744
486000004	0.088836	0.001816
486000005	-0.041654	-0.004457
488000002	1.243006	-0.087172
488000004	0.475631	-0.137667
494000001	-0.011300	-0.045869
494000004	-0.021149	-0.090630
494000005	0.797042	-0.100489
511000001	-0.220121	-0.033714
519000002	0.021961	0.008195
519000003	-0.297805	-0.007519
519000005	-0.100103	-0.002695
535000001	0.037231	0.012693
535000003	0.187671	-0.014850
536000001	0.087309	0.015342
536000002	0.211704	-0.062876
536000003	0.148337	0.013993
536000004	-0.033901	0.027037
536000005	-0.770718	0.009770
538000001	0.223680	0.034981
538000002	0.139817	0.022818
538000004	0.220728	0.015368
538000005	0.294144	0.015454
608000005	-0.081593	-0.004858
639000003	0.086156	0.014823
639000005	0.198588	0.036640
701000001	0.122296	0.055185
701000002	0.099797	0.031131
701000003	-0.099195	-0.012705
701000005	0.104986	0.022148
757000001	0.548975	-0.106312
855000001	-0.083987	-0.027927

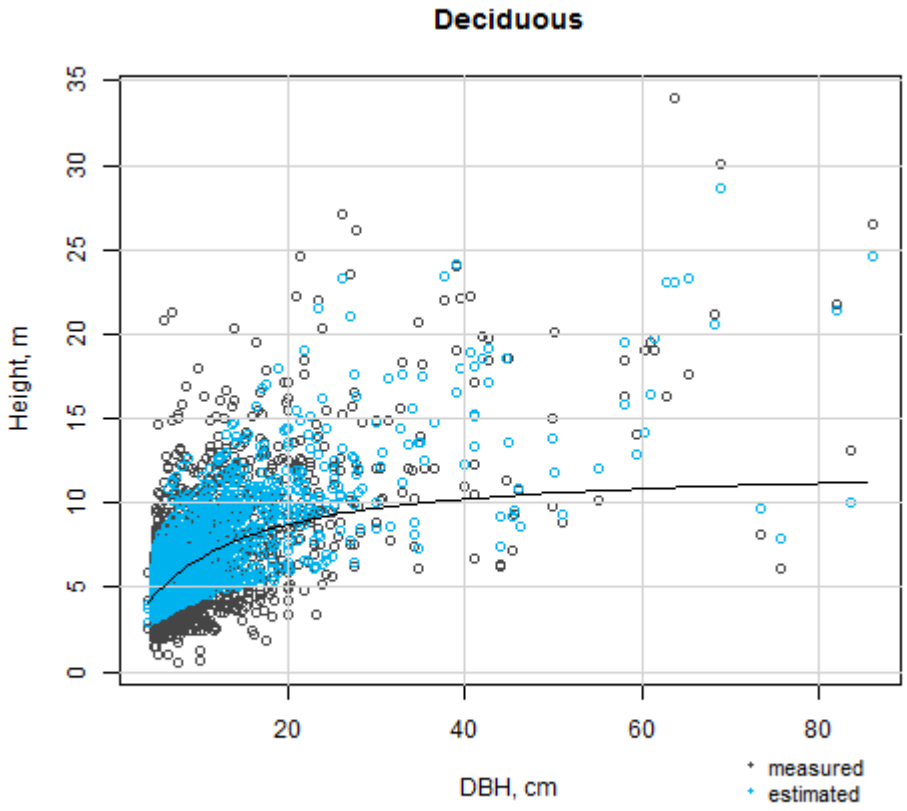
855000004	-0.096726	0.001541
855000005	-0.225397	-0.021521
887000001	0.482433	0.090972
887000002	0.384626	0.065294
887000004	0.345157	0.078867
887000005	0.545860	0.079313
927000001	0.085625	0.012064
927000002	0.117270	0.051925
927000003	0.033940	0.044803
927000004	0.109769	0.022705
927000005	-0.175905	0.073545
929000001	0.228786	0.062485
929000002	0.384171	0.102321
929000003	0.163746	0.072293
929000004	0.201384	0.080942
929000005	0.350489	0.081096
1124000002	0.066537	0.021171
1124000003	-0.076241	-0.019281
1124000005	-0.358968	0.030786
2123000001	-0.518225	0.015005
2123000002	0.012662	-0.058907
2123000005	-0.253120	-0.069748
2173000002	0.236921	0.007746
2173000003	-0.095636	0.037520
2173000004	0.072495	-0.067998
2173000005	-0.294176	-0.012636
2497000003	-0.083331	0.024897
2497000005	0.040663	0.058722
2549000001	-0.119138	-0.009898
2549000002	-0.903488	0.040298
2549000003	-0.145580	-0.018970
2549000004	-0.631592	-0.001572

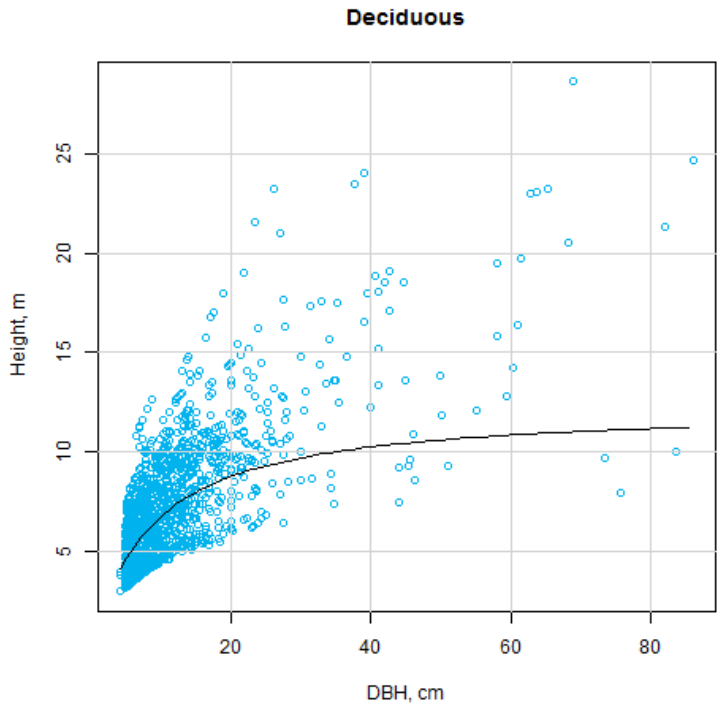
2549000005	-0.906270	0.079095
2606000001	0.493603	0.080599
2606000002	0.303361	0.094315
2606000003	0.222005	0.093908
2606000005	0.221591	0.069713
2616000001	0.227547	0.019076
2616000003	-0.122978	0.011900
2616000004	-0.427218	0.041456
2616000005	0.062708	0.040735
2852000001	0.262157	0.078756
2852000002	-0.039514	0.074026
2852000003	-0.107476	0.026721
2852000004	0.207456	0.064700
2852000005	0.077781	0.039327
2921000001	0.603561	0.071238
2921000004	0.279598	0.060153
2921000005	0.321157	0.040133
2922000001	0.087220	0.006842
2946000001	0.431969	0.062974
2946000002	0.502998	0.041867
2946000003	0.580672	0.059739
2946000004	0.570870	0.081161
2946000005	0.549534	0.040778
7057000001	-0.438898	-0.066063
7057000004	-0.012620	-0.009617
7057000005	0.026170	0.001749
10505000001	-0.109747	0.027338
10505000002	0.106862	0.014477
10505000003	0.139893	0.038738
10505000004	0.154350	0.012555
10505000005	0.007357	0.012386
11311000001	-0.290761	-0.087898

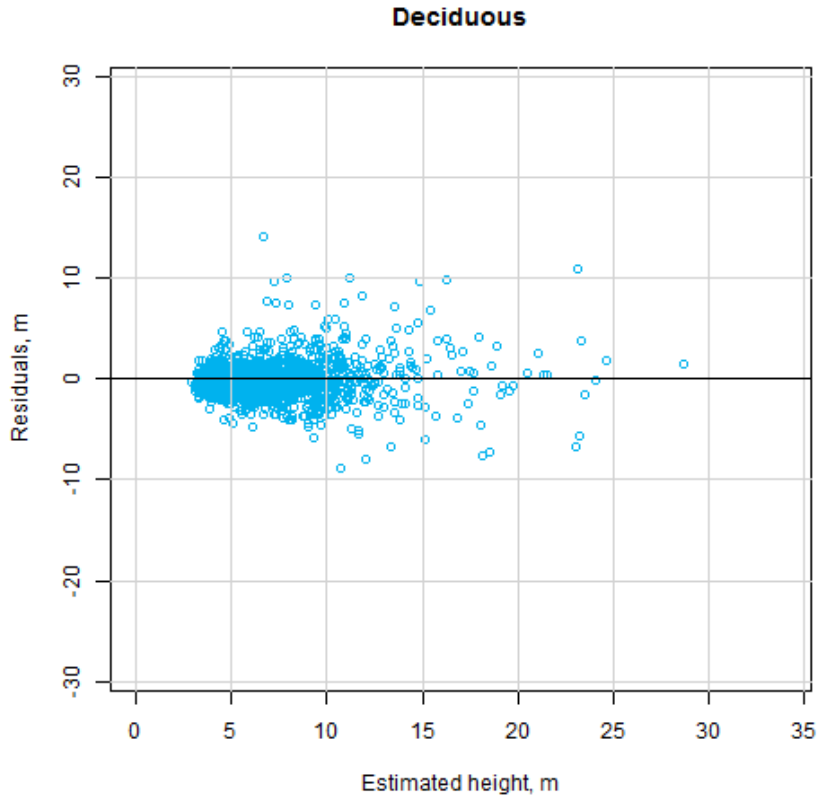
11311000002	-0.564972	-0.074913
11311000003	-0.658069	-0.047650
11311000004	-0.087244	0.036536
11311000005	0.428687	-0.145061
11743000002	0.090948	-0.097597
11743000003	-0.067632	-0.038381
11923000001	-0.256157	-0.105917
11923000002	0.847064	-0.133858
11923000003	-0.099276	-0.020936
11923000005	-0.024013	-0.053176
13925000001	-0.172579	-0.047930
13925000002	-0.091814	0.028857
13925000004	0.032618	-0.076953
14115000005	-0.046338	0.038477
15567000001	-0.424135	-0.026738
15567000002	-0.322967	-0.030592
15567000003	0.254889	-0.102602
15567000004	-0.263131	-0.064177
15567000005	-0.502841	-0.019566
15973000001	-0.604873	-0.022285
15973000002	-0.112301	-0.076276
15973000004	-0.471551	-0.026354
15973000005	-0.220620	-0.003795
16141000001	0.190100	0.059699
16141000002	0.286847	0.035098
16141000003	0.296757	0.075279
16141000005	0.230927	0.098601
16145000001	0.098173	0.070177
16145000002	0.193133	0.086504
16145000004	-0.064520	0.026163
16145000005	0.054127	0.090460
17562000001	0.154930	0.023600

17562000002	0.144353	0.034315
17562000004	0.227159	0.075515
17562000005	0.076016	0.071345
18605000001	0.144344	-0.058714
18605000002	-0.366364	-0.081652
18605000003	-0.118064	-0.030003
18605000004	-0.213478	0.002155
18605000005	-0.306082	0.021028
19011000005	-0.023520	0.043499
21799000003	0.164066	0.017823
21799000004	-0.083019	0.071313
21799000005	0.093512	0.016465
26271000001	-0.187075	-0.033153
26271000002	-0.383202	-0.026425
26271000003	-0.451108	-0.031107
26271000004	-0.038715	-0.037007
26271000005	-0.015607	-0.029515
27269000004	0.046270	0.006672
58372000001	0.824224	-0.171068
58372000003	0.089525	-0.064209
58372000004	-0.019218	0.017198
58372000005	-0.005666	-0.070151
76186000001	0.398908	-0.036911
76186000002	0.446453	-0.029589
76186000003	-0.606616	-0.084945
76186000004	-0.627951	0.031455
76186000005	-0.689717	-0.018376
191832000001	-0.104379	-0.013408
191832000002	-0.133130	-0.000353
191832000003	-0.139888	0.014276
191832000004	-0.048522	0.014307
191832000005	-0.218814	-0.003618

235062000002	-0.536320	-0.052833
235062000003	-0.561328	-0.032696
235062000004	-0.155429	-0.041437
235062000005	-0.675412	-0.030710
315476000002	-0.023473	-0.002117
315476000004	0.164477	-0.097429
315476000005	0.466872	-0.116584




Deciduous
Height, m
5
10
15
20
25
20
40
60
80
DBH, cm


Deciduous
Residuals, m
30
20
10
0
-10
-20
-30
0
5
10
15
20
25
30
35
Estimated height, m

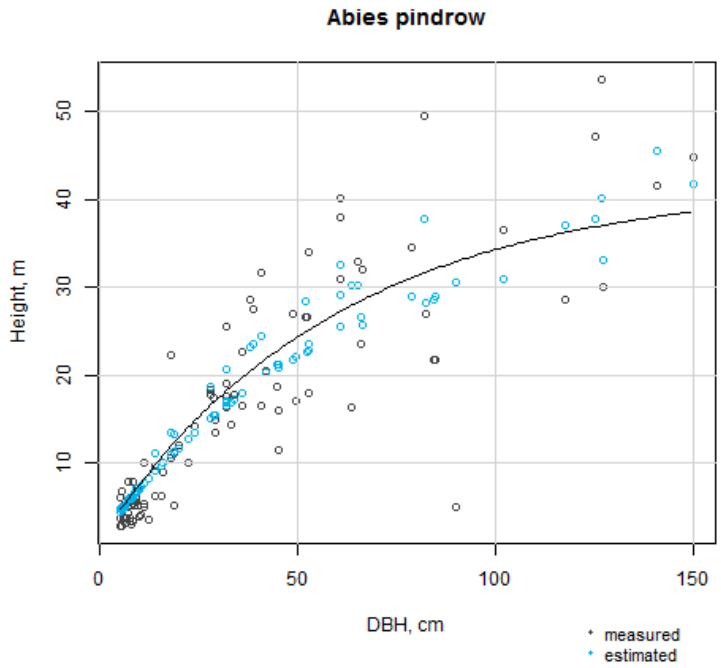
d = diameter at breast height

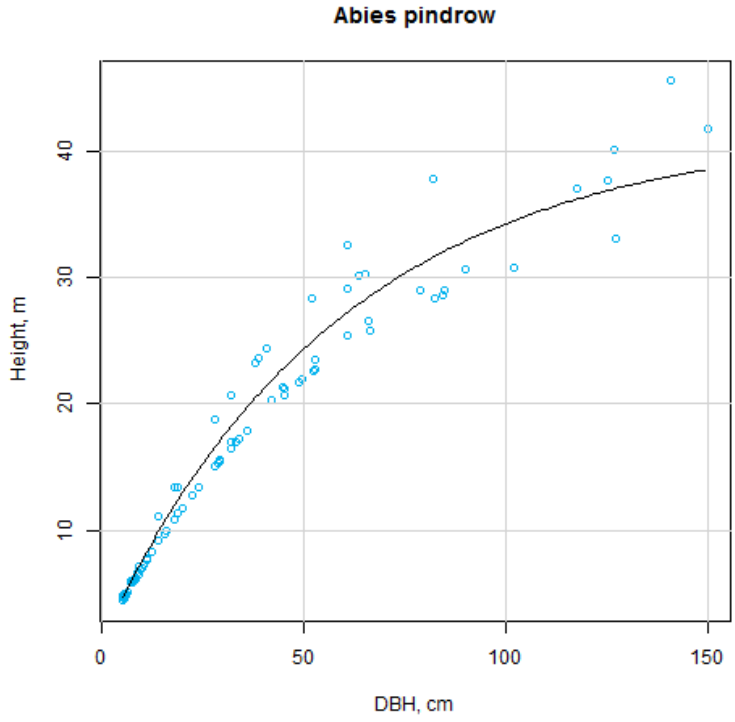
h = tree height

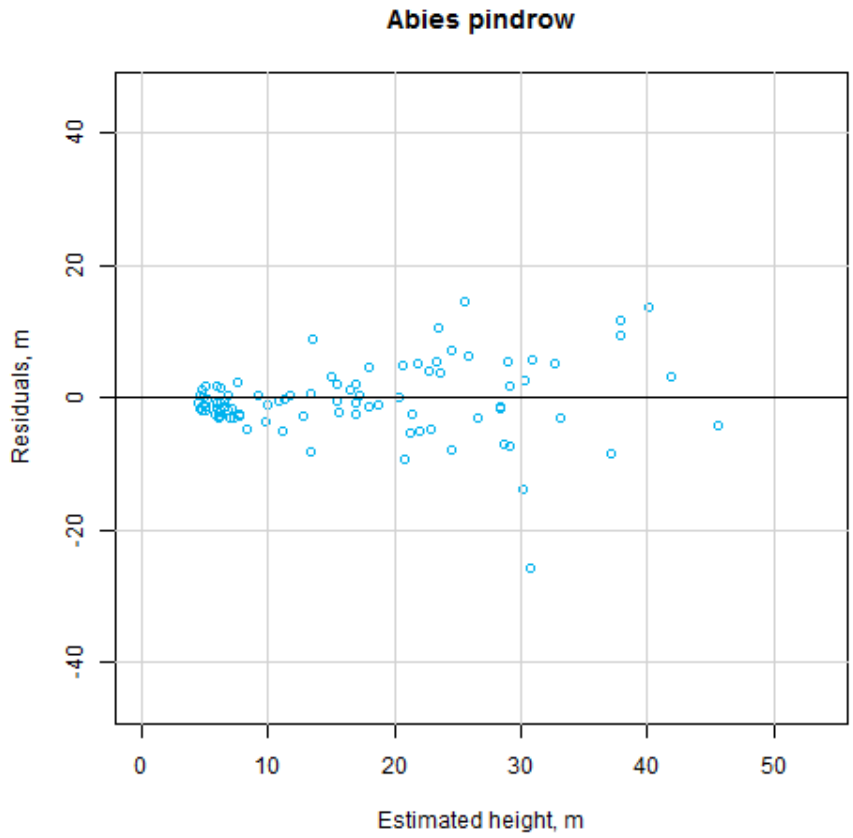
h = a*(1-exp(-b*d)) (Meyer model)

Abies pindrow

Plot id cluster00000plot	a	b
344000001	-2.864809	0.0000005
344000003	-4.091523	0.0000007
344000004	5.937143	-0.0000010
344000005	3.509511	-0.0000007
488000002	-4.472955	0.0000008
488000003	8.331603	-0.0000014
488000004	2.999915	-0.0000005
494000001	-0.477956	0.0000001
494000004	-3.903695	0.0000007
494000005	-3.037402	0.0000005
5839000001	-3.010084	0.0000005
5839000002	0.977018	-0.0000002
7057000004	0.103233	0.0000000

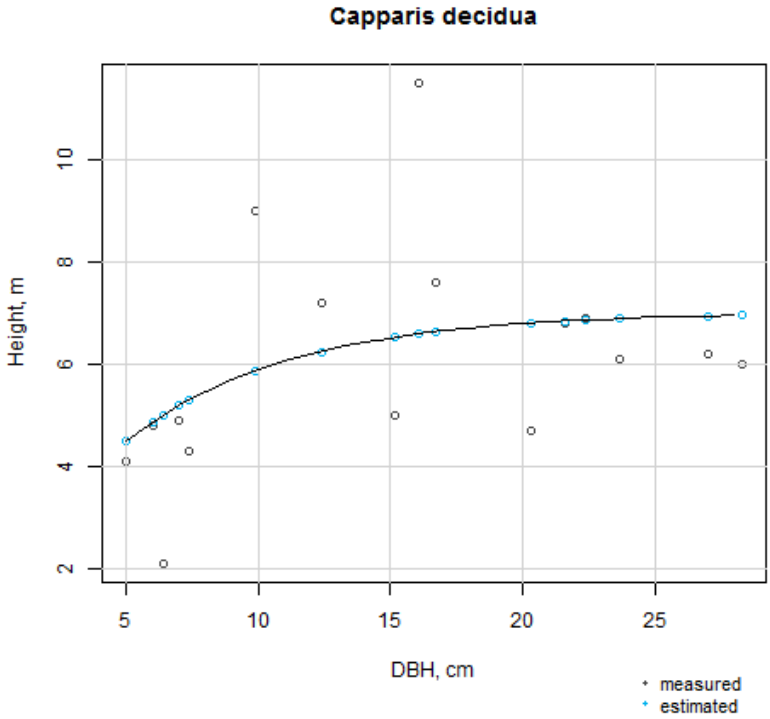

Abies pindrow
Height, m
10
20
30
40
50
0
50
100
150
DBH, cm
measured
estimated

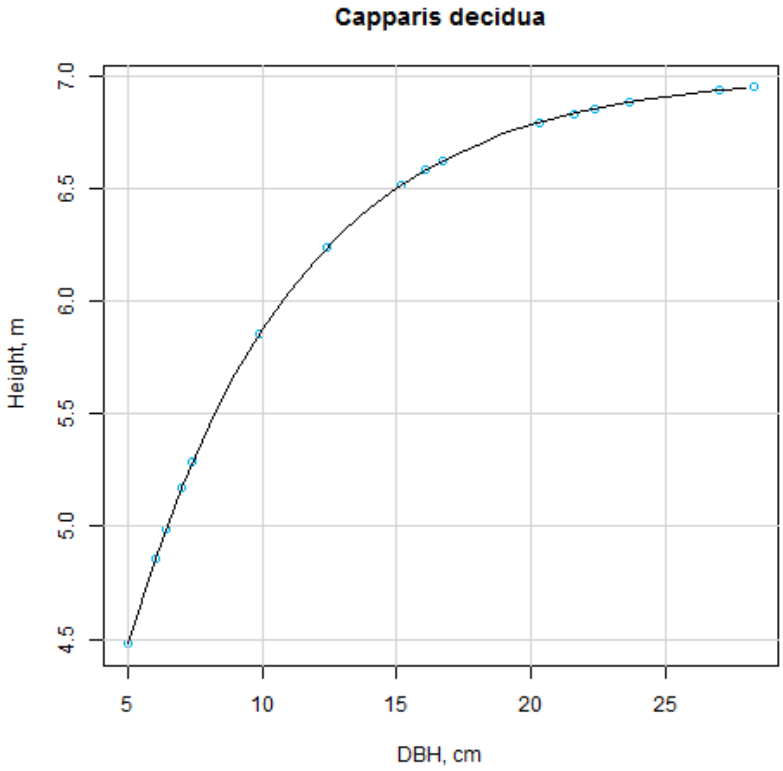

Abies pindrow
Height, m
10
20
30
40
0
50
100
150
DBH, cm

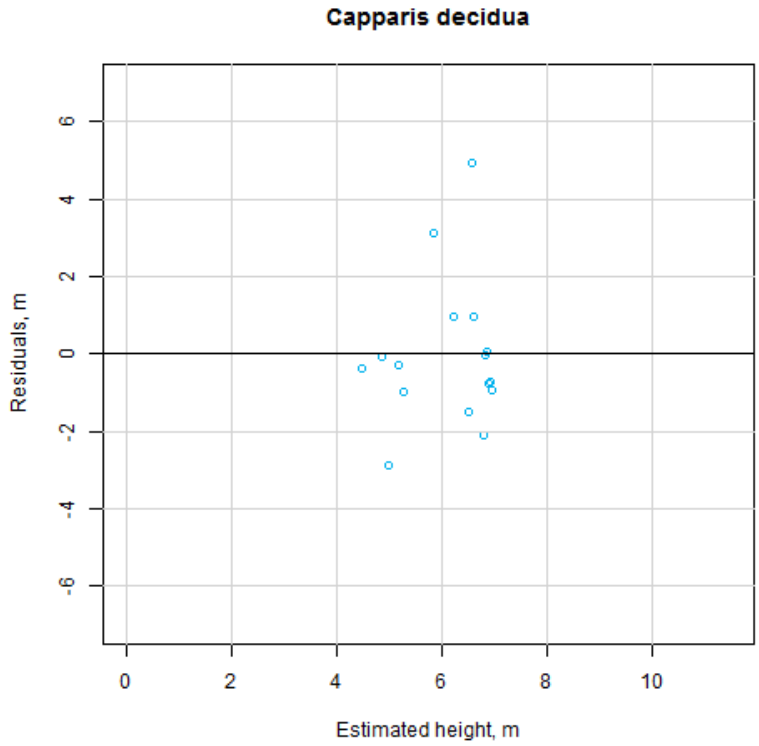


Capparis decidua

Plot id cluster00000plot	a	b
19011000001	-0.0000000003	-0.0000000019
19011000002	0.0000000014	0.0000000154
19011000004	-0.0000000010	-0.0000000121
27269000001	-0.0000000001	-0.0000000013


Capparis decidua
Height, m
DBH, cm
measured
estimated


Capparis decidua
Height, m
DBH, cm



d = diameter at breast height

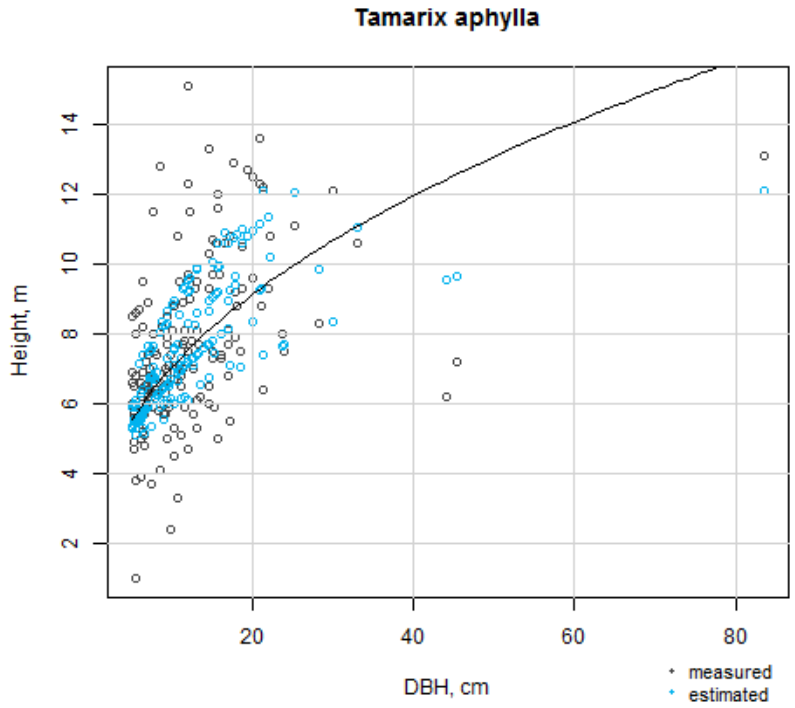
h = tree height

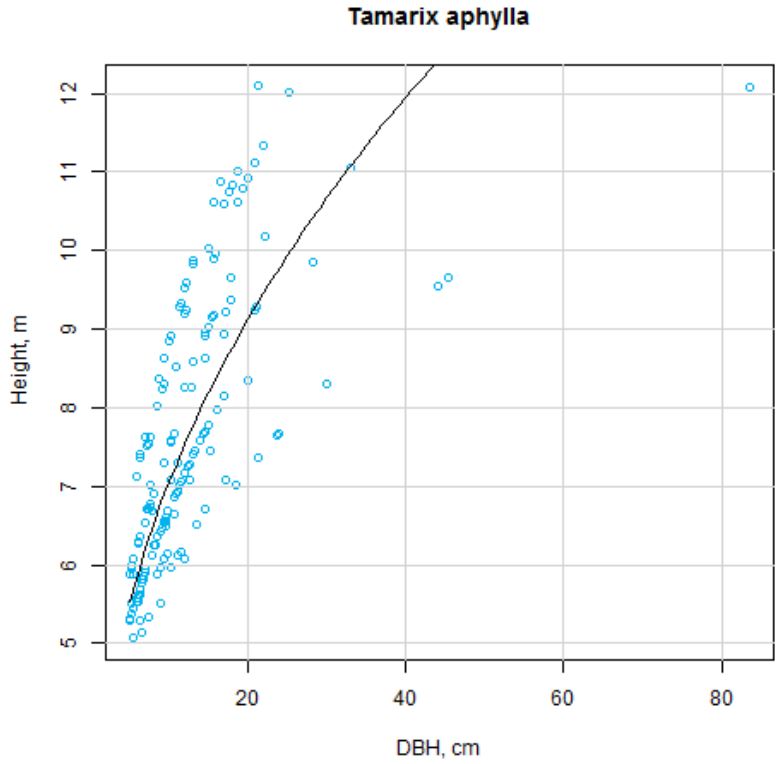
h = a*d^b (Power model)

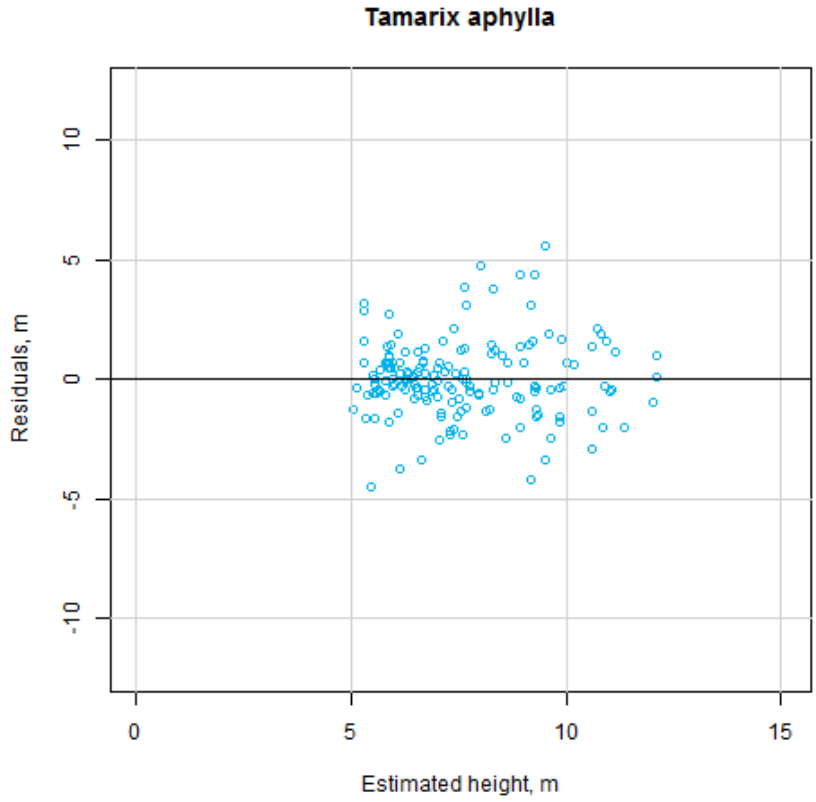
Tamarix aphylla

Plot id cluster00000plot	a	b
855000004	-0.106917	-0.006692
855000005	-0.102290	-0.006407
1124000005	-0.090621	-0.005790
2123000001	0.135414	0.008467
2123000002	-0.039431	-0.002463
2123000005	0.154223	0.009650
2173000002	-0.149441	-0.009334
2173000003	-0.241854	-0.015179
2173000005	0.066922	0.004196
2549000001	0.104894	0.006577
2549000003	0.062625	0.003916

2549000005	-0.140495	-0.008822
2606000005	-0.173244	-0.010888
2616000001	-0.383650	-0.024167
2616000003	-0.102794	-0.006446
2616000004	-0.090138	-0.005809
2616000005	-0.327807	-0.020551
21799000003	-0.132125	-0.008255
26271000001	0.322968	0.020350
26271000002	0.390394	0.024458
26271000003	0.463844	0.029189
26271000004	0.183760	0.011582
26271000005	0.120892	0.007684
76186000001	-0.002565	-0.000053
76186000004	0.077433	0.004789




Tamarix aphylla
Height, m
DBH, cm
5
6
7
8
9
10
11
12
20
40
60
80


Tamarix aphylla
Residuals, m
Estimated height, m
-10
-5
0
5
10
0
5
10
15

Annex 5 Report on Forest Boundary Survey and Mapping

Background

One of the outputs of the assignment, under the NFMS and MRV is reporting on boundary demarcation of forest and pilot forest land zoning system in ten sample districts. This stipulated output has not been well defined in terms of relation to other scope of works and does not appear to be in conjunction with the requirements of NFMS and MRV.

The requirement of this output and its scope was discussed with the National REDD+ Team on 22nd February 2017, with a recommendation to pilot an exercise to demarcate forest compartment boundary in the field and develop a methodological guideline document.

The pilot exercise was done in representative forests compartments in three districts of Punjab (Chakwal, Jehlum and Rawalpindi) and six compartments in Manshera in KP. This short report presents the methodology adopted and output of the piloting exercise.

Objectives and Scope of Works

As stipulated in the project ToR, the objective of this exercise is to pilot forest compartment level boundary delineation in the field and prepare a methodological guideline that can be followed for replication and upscaling by the provincial Forest Departments. The delineated compartment level forest boundaries are expected to be integrated into the proposed NFMS information platform. The scope of works under this are:

- Develop a field-based methodology to delineate/demarcate forest compartment boundaries using Differential GPS and other field survey equipment as necessary.
- Test and pilot the field exercise to delineate/demarcate forest compartment boundaries in sample districts. This will include updating of the forest boundaries in sample districts mapped by WWF.
- Document the method implemented, accuracy achieved and prepare a methodological guideline document (protocol) that can be followed by provincial Forest Departments.
- Develop a process to integrate the delineated forest boundary GIS and attribute data into the National Forest Monitoring System

Methodology

1. Selection of sample forest areas for piloting in consultation with concerned forest departments. Pilot areas were selected in consultation with concerned forest department personnel and avoiding any areas with boundary conflicts supported by spatial criteria related to the accessibility, also considering time taken for the field works.
2. Reviewing of existing Forest History Files, Massavi maps and relevant topographic maps. Planning of field survey using Google Earth images.
3. Reconnaissance survey and identification of forest boundary (boundary pillars) by Forest Dept. Demarcation Division/Unit personnel along with WWF-Pakistan survey team. Consultation with the local forest users and community was done for preliminary identification of forest boundaries and existing boundary pillars.
4. DGPS Ground Controls Points (GCPs) were established covering the range of forest to be surveyed (within 5-10 km). If the National GPS points with known coordinates are available, GCPs can be established in such points. Otherwise, independent GCP can be established at permanent reference locations. The DGPS recording at the reference GCP stations were continuously taken during the period of forest boundary survey.
5. Kinematic DGPS survey along the identified forest boundaries were done by traversing the forest boundary.
6. Post processing of Kinematic DGPS survey data were done back in the office.
7. Forest boundaries were mapped in GIS environment and collected attribute data integrated.
8. Methodological protocol for undertaking similar exercise by the Forest Departments was prepared.
9. A module was developed in the NFMS to integrate field surveyed and mapped forest boundaries into the NFMS GIS database.

Figure 22 DGPS base station being established in one of the forest boundary pillars (Jhelum, PB).

Figure 23 DGPS rover station on top of an unmarked forest boundary in Manshera, KP

Figure 24 DGPS rover station being established in a forest boundary in pillar Manshera, KP.

Piloting Results

Compartment 1 Chakwal, Punjab

Forest Name	Jabwal
Compartment	P-4
Forest Sub-Division	Chakwal
Village/Settlement	Rakh Jabwal
District	Chakwal
Province	Punjab
Area (Ha)	9.4
No. of Pillars	35

Point Id	Latitude	Longitude	Height	Description	Pillar Conditions
P001	32.968123	72.817444	440.869200	Concrete pillar	Good
P002	32.968369	72.818170	445.195500	Concrete pillar	Good
P003	32.968610	72.817917	443.623900	Concrete pillar	Good
P004	32.968858	72.817388	439.840100	Concrete pillar	Good
P005	32.968890	72.816672	440.558100	No pillar	Nonexistent
P006	32.969971	72.814353	439.022500	Concrete pillar	Good
P007	32.969735	72.814253	439.365100	No pillar	Nonexistent
P008	32.969823	72.814067	438.825500	Concrete pillar	Good
P009	32.968709	72.813413	436.797700	Concrete pillar	Good
P010	32.967657	72.812870	441.295800	Concrete pillar	Good
P011	32.966611	72.813993	443.065500	Concrete pillar	Good
P012	32.966148	72.813969	444.398200	Concrete pillar	Good
P013	32.965703	72.813204	444.050600	Concrete pillar	Good
P014	32.965985	72.812488	443.039200	Concrete pillar	Poor
P015	32.965735	72.812379	441.507300	Concrete pillar	Poor
P016	32.965731	72.812381	441.568300	No pillar	Nonexistent
P017	32.965886	72.811267	438.137100	No pillar	Nonexistent
P018	32.965329	72.811214	439.879000	No pillar	Nonexistent

P019	32.965103	72.813019	445.785800	Concrete pillar	Good
P020	32.965824	72.814119	446.531500	Concrete pillar	Good
P021	32.965479	72.814338	446.309000	Concrete pillar	Good
P022	32.964784	72.813412	444.350600	Concrete pillar	Good
P023	32.964518	72.814248	447.752600	Concrete pillar	Good
P024	32.965382	72.814864	447.653900	Concrete pillar	Good
P025	32.966248	72.814524	444.460300	Concrete pillar	Good
P026	32.966505	72.814398	442.841700	Concrete pillar	Good
P027	32.968064	72.814507	438.272200	Concrete pillar	Good
P028	32.968614	72.815032	439.311900	Concrete pillar	Good
P029	32.968615	72.815031	439.337700	Concrete pillar	Good
P030	32.968418	72.815839	440.313600	Concrete pillar	Good
P031	32.968814	72.816241	438.617600	Concrete pillar	Good
P032	32.968292	72.816586	440.212000	Concrete pillar	Good
P033	32.968137	72.816837	438.811900	Concrete pillar	Good
P034	32.968100	72.817109	440.881200	Concrete pillar	Good
P035	32.968110	72.817436	439.673100	Concrete pillar	Good

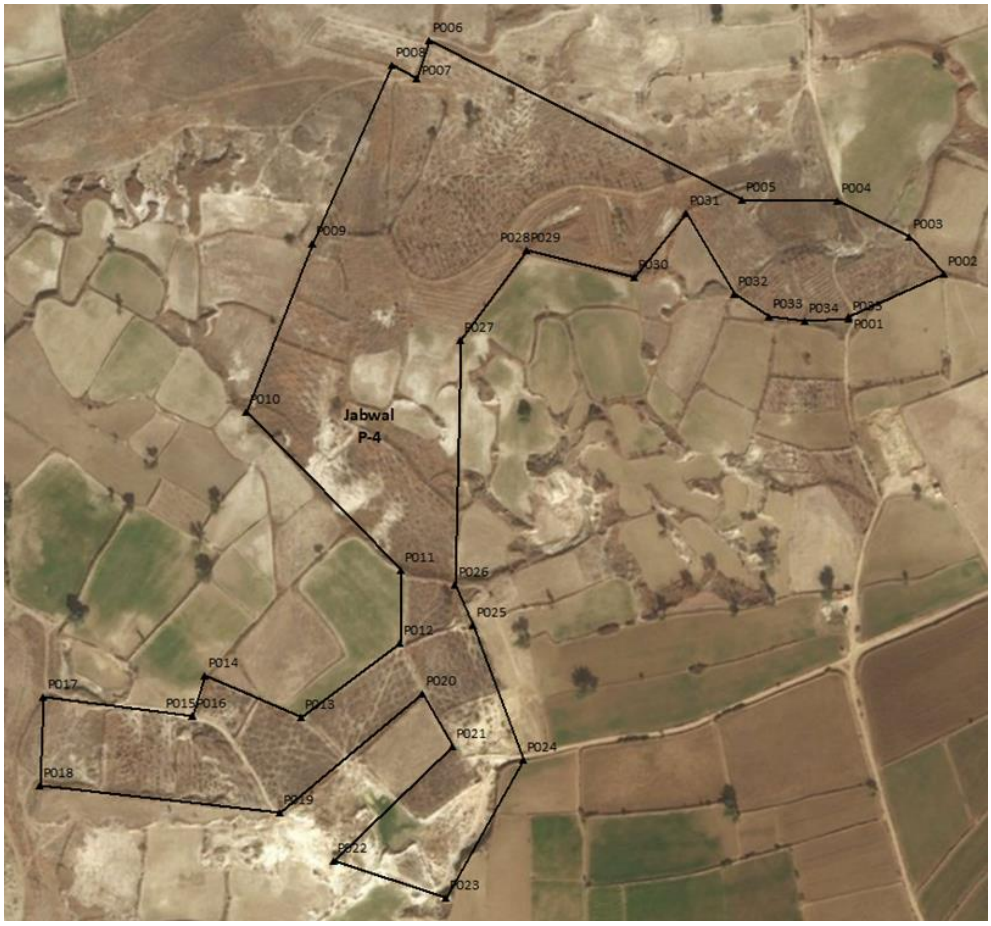


Figure 25 Map of surveyed boundary of Jabwal Forest Compartment P-4, Chakwal Forest Division, Chakwal

Compartment 2 Chakwal, Punjab

Forest Name	Warhal
Compartment	1
Forest Sub-Division	Chakwal
Village/Settlement	Warhal
District	Chakwal
Province	Punjab
Area (Ha)	28.42
No. of Pillars	20

Point Id	Latitude	Longitude	Height	Description	Pillar Condition
P001	32.8151390	72.6428951	586.2134000	Concrete pillar with exposed iron rod	Good
P002	32.8153691	72.6422440	585.9100000	Concrete pillar with exposed iron rod	Good
P003	32.8174289	72.6421450	583.6110000	Concrete pillar with exposed iron rod	Good
P004	32.8188753	72.6415470	592.3898000	Concrete pillar with exposed iron rod	Good
P005	32.8194308	72.6401621	589.2296000	Concrete pillar with exposed iron rod	Good
P006	32.8203640	72.6398430	584.8848000	Concrete pillar with exposed iron rod	Good
P007	32.8203707	72.6384665	585.4324000	Concrete pillar with exposed iron rod	Good
P008	32.8205331	72.6367176	595.7737000	Concrete pillar with exposed iron rod	Good
P009	32.8223691	72.6350338	590.2262000	Concrete pillar with exposed iron rod	Good
P010	32.8236483	72.6373715	584.6309000	Concrete pillar with exposed iron rod	Good
P011	32.8235686	72.6386575	581.9422000	Concrete pillar with exposed iron rod	Good
P012	32.8240319	72.6385926	582.8839000	Concrete pillar with exposed iron rod	Good
P013	32.8241604	72.6394006	581.4094000	Concrete pillar with exposed iron rod	Good
P014	32.8245968	72.6397470	583.5452000	Concrete pillar with exposed iron rod	Good
P015	32.8245997	72.6405804	577.6006000	Concrete pillar with exposed iron rod	Good
P016	32.8217299	72.6400353	580.4151000	Concrete pillar with exposed iron rod	Good
P017	32.8211785	72.6412301	578.2511000	Concrete pillar with exposed iron rod	Good
P018	32.8210006	72.6418982	579.7518000	Concrete pillar with exposed iron rod	Good
P019	32.8205625	72.6436528	582.7218000	Concrete pillar with exposed iron rod	Good
P020	32.8200066	72.6441215	584.4920000	Concrete pillar with exposed iron rod	Good

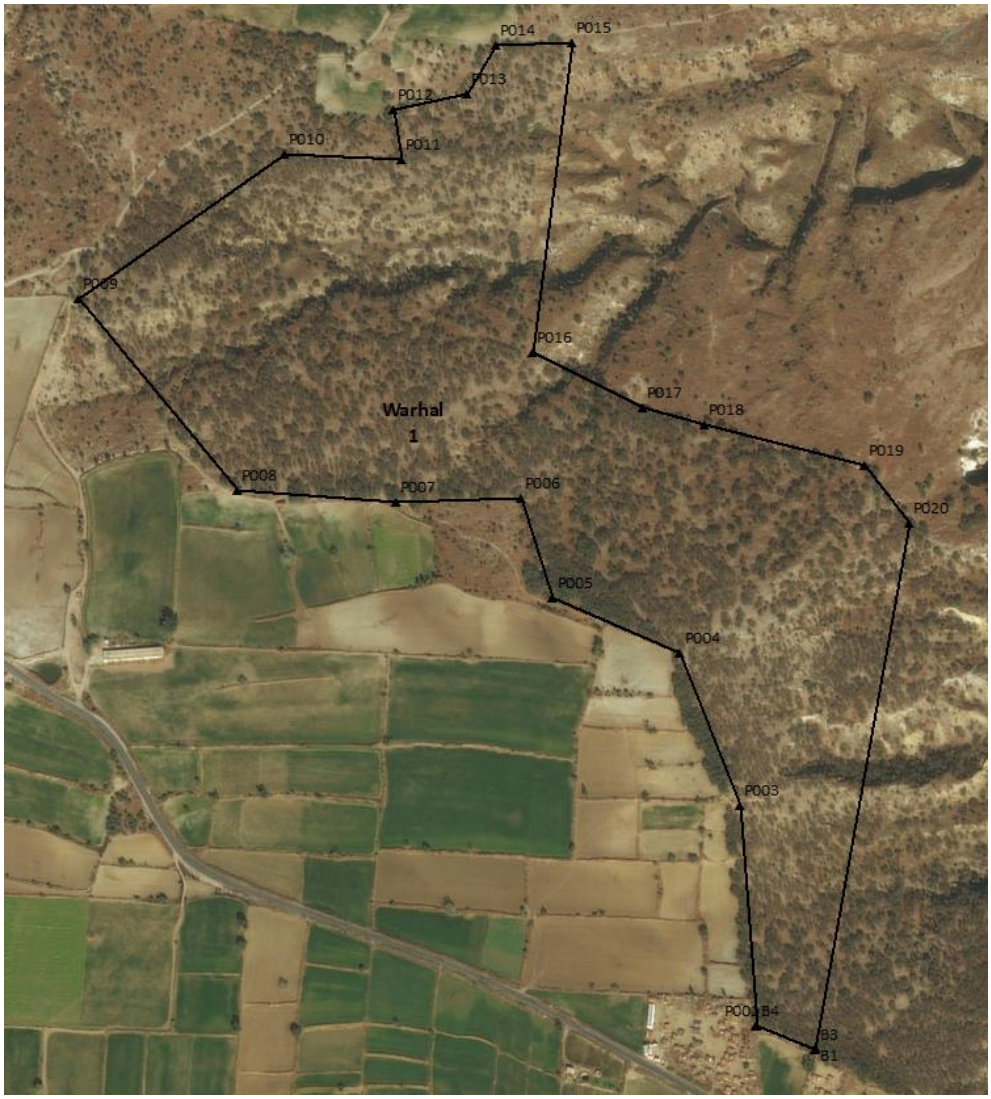


Figure 26 Map of surveyed boundary of Warhal Forest Compartment 1, Chakwal Forest Division, Chakwal, PB

Compartment 3 Jhelum, Punjab

Forest Name	Betalidher
Compartment	2
Forest Sub-Division	Sohawa
Village/Settlement	Betalidher
District	Jhelum
Province	Punjab
Area (Ha)	78.98
No. of Pillars	19

Point Id	Latitude	Longitude	Height	Description	Pillar Conditions
P001	33.043754	73.536026	289.727	Pile of stones	Nonexistent
P002	33.044166	73.534426	288.264	Pile of stones	Nonexistent
P003	33.047378	73.534478	287.502	Pile of stones	Nonexistent
P004	33.048507	73.535220	283.393	Pile of stones	Nonexistent
P005	33.049485	73.535940	282.157	Pile of stones	Poor
P006	33.051079	73.536093	291.222	Pile of stones	Poor
P007	33.051326	73.535817	299.687	On the ridge	Nonexistent
P008	33.055534	73.536142	237.640	No pillar	Good
P009	33.058541	73.529182	284.244	Concrete pillar	Nonexistent
P010	33.059421	73.529195	279.592	No pillar, ridge	Nonexistent
P011	33.057078	73.533217	236.787	Natural ground under *Acacia nilotica*	Nonexistent
P012	33.057088	73.540614	236.214	No pillar	Nonexistent
P013	33.053438	73.538913	252.989	No pillar, rocky terrain	Nonexistent
P014	33.049657	73.540143	242.456	No pillar	Nonexistent
P015	33.049667	73.544403	275.262	Temporary mark	Nonexistent
P016	33.047597	73.542742	283.999	Temporary mark	Nonexistent
P017	33.045856	73.542096	282.419	Temporary mark	Nonexistent
P018	33.044557	73.542008	275.925	Temporary mark	Nonexistent

P019	33.043763	73.536023	286.336	Temporary mark	Nonexistent

Figure 27 Map of surveyed boundary of Betalidher Forest Compartment 1, Sohawa Forest Division, Jhelum, PB

Compartment 4 Manshera, KP

Forest Name	Batrasi
Compartment	2 (1)
Forest Sub-Division	Manshera
Division	Siran
Village/Settlement	Batrasi Baghlchar
District	Manshera
Province	Khyber Pakhtunkhwa
Area (Ha)	48.39
No. of Pillars	15

Point Id	Latitude	Longitude	Height	Description	Pillar Conditions
P001	34.402298	73.338075	1132.000	No pillar	Nonexistent
P002	34.405062	73.338142	1165.733	No pillar	Nonexistent
P003	34.408947	73.339136	1211.587	No pillar	Nonexistent
P004	34.411540	73.339307	1222.995	No pillar	Nonexistent
P005	34.411797	73.343086	1065.597	No pillar	Nonexistent
P006	34.412553	73.349810	953.473	No pillar/ road side	Nonexistent
P007	34.412305	73.348979	952.287	No pillar/ road side	Nonexistent
P008	34.411985	73.347447	955.201	No pillar/ road side	Nonexistent
P009	34.411430	73.348249	959.472	No pillar/ road side	Nonexistent
P010	34.410401	73.345902	982.264	No pillar/ road side	Nonexistent
P011	34.408380	73.343810	1014.069	Concrete pillar	Good
P012	34.407141	73.343715	1029.418	No pillar/	Nonexistent

				road side	
P013	34.404367	73.340018	1075.834	No pillar/ road side	Nonexistent
P014	34.400946	73.341350	1107.062	No pillar/ road side	Nonexistent
P015	34.400709	73.340487	1116.209	No pillar/ road side	Nonexistent

Compartment 5 Manshera, KP

Forest Name	Batrasi
Compartment	3 (2)
Forest Sub-Division	Manshera
Division	Siran
Village/Settlement	Batrasi Baghlchar
District	Manshera
Province	Khyber Pakhtunkhwa
Area (Ha)	77.83
No. of Pillars	15

PointId	Latitude	Longitude	Height	Description	Pillar Conditions
P001	34.399425	73.348178	947.619	Concrete Pillar	Good
P002	34.401877	73.349474	862.073	Concrete Pillar	Good
P003	34.404622	73.349309	921.479	Concrete Pillar	Good
P004	34.408159	73.348713	917.921	Concrete Pillar	Good
P005	34.412385	73.350318	967.492	Concrete Pillar	Good
P006	34.400703	73.341488	1108.105	No pillar	Nonexistent

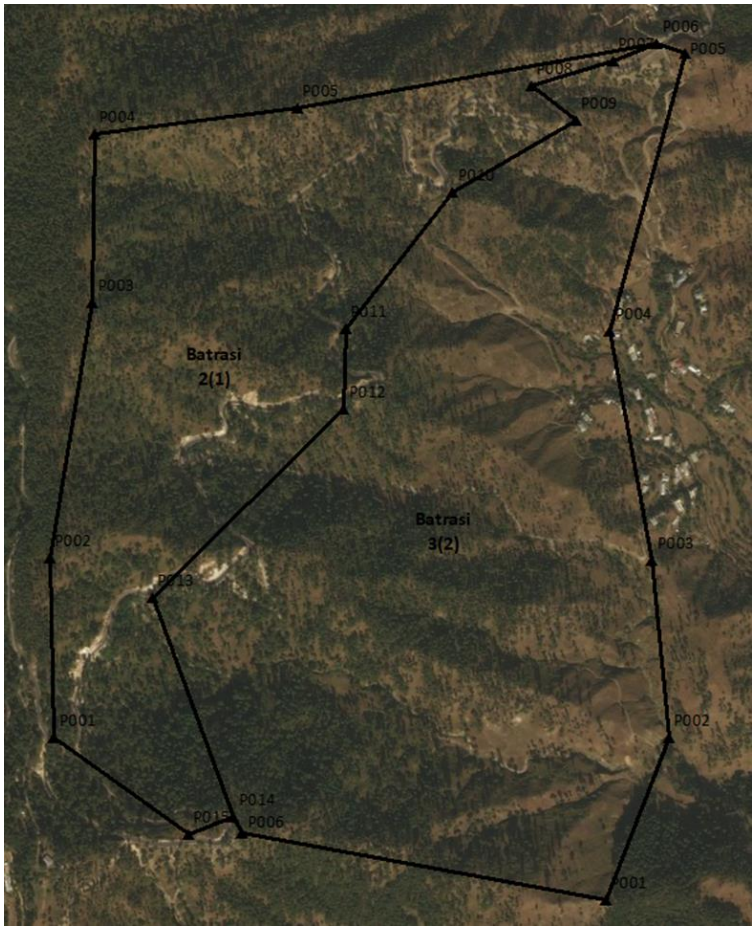


Figure 28 Map of surveyed boundary of Batrasi Forest Compartments 2(1) and 3(2), Siran Forest Division, Manshera, KP

Compartment 6 Manshera, KP

Forest Name	Kakku
Compartment	14
Forest Sub-Division	Gidarpur
Division	Agror Tanawal
Village/Settlement	Khandheri
District	Manshera
Province	Khyber Pakhtunkhwa
Area (Ha)	28.4
No. of Pillars	15

Point Id	Latitude	Longitude	Height	Description	Pillar Conditions
P001	34.4785267	73.12551515	1125.84	Concrete Pillar	Good
P002	34.4799264	73.12373885	1147.81	Concrete Pillar	Poor
P003	34.4823253	73.12160183	1233.45	No pillar/Natural ground	Nonexistent
P004	34.4843963	73.12063256	1309.48	Concrete Pillar	Good
P005	34.4852709	73.11854672	1366.3	Concrete Pillar	Poor
P006	34.4873593	73.11912604	1380.26	Turning Point	Nonexistent
P007	34.4868583	73.12189248	1237.13	No pillar/Natural ground	Nonexistent
P008	34.4853797	73.12312714	1213.86	Turning Point	Nonexistent
P009	34.4840081	73.12335533	1191.24	Turning Point	Nonexistent
P010	34.4824945	73.12410418	1157.83	Turning Point	Nonexistent
P011	34.4797238	73.12705656	1111.54	Concrete Pillar	Good
P012	34.4785591	73.1282708	1087.39	Concrete Pillar	Good
P013	34.4779766	73.12805196	1073.23	Concrete Pillar	Good
P014	34.4777708	73.12686051	1091.05	Concrete Pillar	Good
P015	34.4777075	73.12655944	1102.82	No pillar/Natural ground	Nonexistent

Compartment 7 Manshera, KP

Forest Name	Kakku
Compartment	15
Forest Sub-Division	Gidarpur
Division	Agror Tanawal
Village/Settlement	Khandheri
District	Manshera
Province	Khyber Pakhtunkhwa
Area (Ha)	53.07
No. of Pillars	16

Point Id	Latitude	Longitude	Height	Description	Conditions
P0001	34.47852667	73.12551515	1039.801	Concrete pillar	Bad
P0002	34.47992644	73.12373885	1020.603	Concrete pillar	Good
P0003	34.48232525	73.12160183	976.3736	Concrete pillar	Good
P0004	34.48439628	73.12063256	925.5274	Concrete pillar	Good
P0005	34.48527091	73.11854672	917.1845	Concrete pillar	Bad
P0006	34.48735927	73.11912604	921.4873	Concrete pillar	Good
P0007	34.48685826	73.12189248	935.6105	Concrete pillar	Good
P0008	34.48537972	73.12312714	939.7375	Concrete pillar	Good
P0009	34.48400808	73.12335533	933.4065	Concrete pillar	Good
P0010	34.48249447	73.12410418	1199.006	No pillar/ Natural Ground	Nonexistent
P0011	34.47972375	73.12705656	1198.024	No pillar/ Natural Ground	Nonexistent
P0012*	34.47855909	73.1282708	1176.756	No pillar/ Natural Ground	Nonexistent
P0013	34.47797664	73.12805196	1159.678	No pillar/ Natural Ground	Nonexistent
P0014	34.47777079	73.12686051	1134.334	No pillar/ Natural Ground	Nonexistent
P0015	34.47770755	73.12655944	1108.089	Concrete pillar	Good
P0016	34.48072944	73.126102	1100.312	No pillar/ Natural Ground	Nonexistent

*P0012 has encountered DGPS observational error, therefore is not considered for boundary mapping of Kakku Forest Compartment 15.

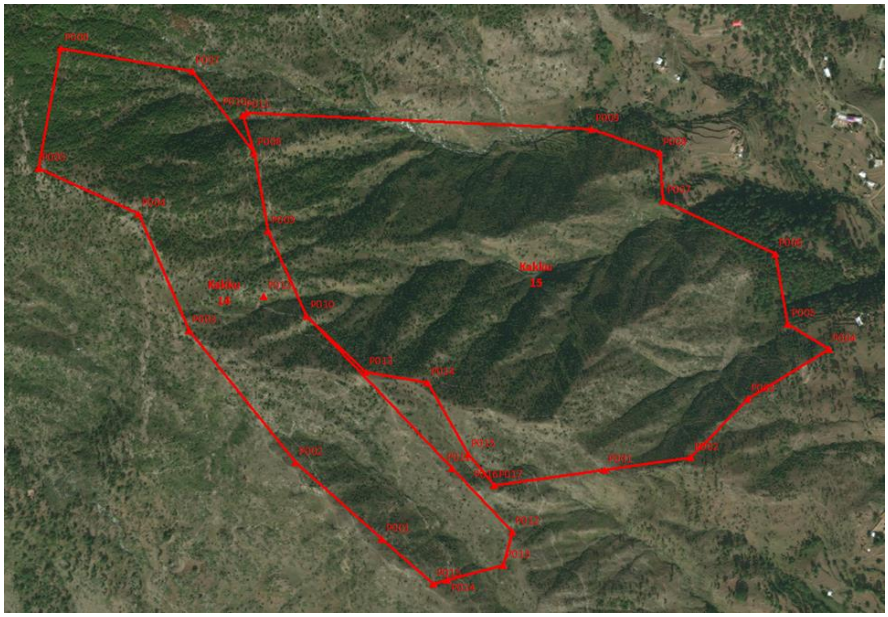


Figure 29 Map of surveyed boundary of Kakku Forest Compartments 14 and 15, Agror Tanawal Forest Division, Manshera, KP

Compartment 8 Manshera, KP

Forest Name	Malakandi-1
Compartment	2(1)
Forest Sub-Division	Balakot
Division	Kaghan
Village/Settlement	Shogran
District	Manshera
Province	Khyber Pakhtunkhwa
Area (Ha)	70.75
No. of Pillars	11

Point Id	Latitude	Longitude	Height	Description	Pillar Conditions
P001	34.642522088	73.463763803	2283.68	Concrete pillar	Good
P002	34.640194046	73.467505349	2329.81	Concrete pillar	Good
P003	34.639719530	73.477921225	2570.76	Temporary point	Non existent
P004	34.640591411	73.477690102	2573.85	Concrete pillar	Good
P005	34.642636827	73.480014849	2444.61	No Pillar/Natural Ground	Non existent
P006	34.647689356	73.482912864	2103.76	Concrete pillar	Good
P007	34.646108049	73.478954238	2141.39	Turning point	Non existent
P008	34.645706987	73.474813224	2133.25	Turning point	Non existent
P009	34.641945514	73.468233583	2155.9	No Pillar/Natural Ground	Non existent
P010	34.644519494	73.463323360	2183.24	No Pillar/Natural Ground	Non existent
P011	34.640987956	73.462720172	2304.11	Concrete pillar	Good

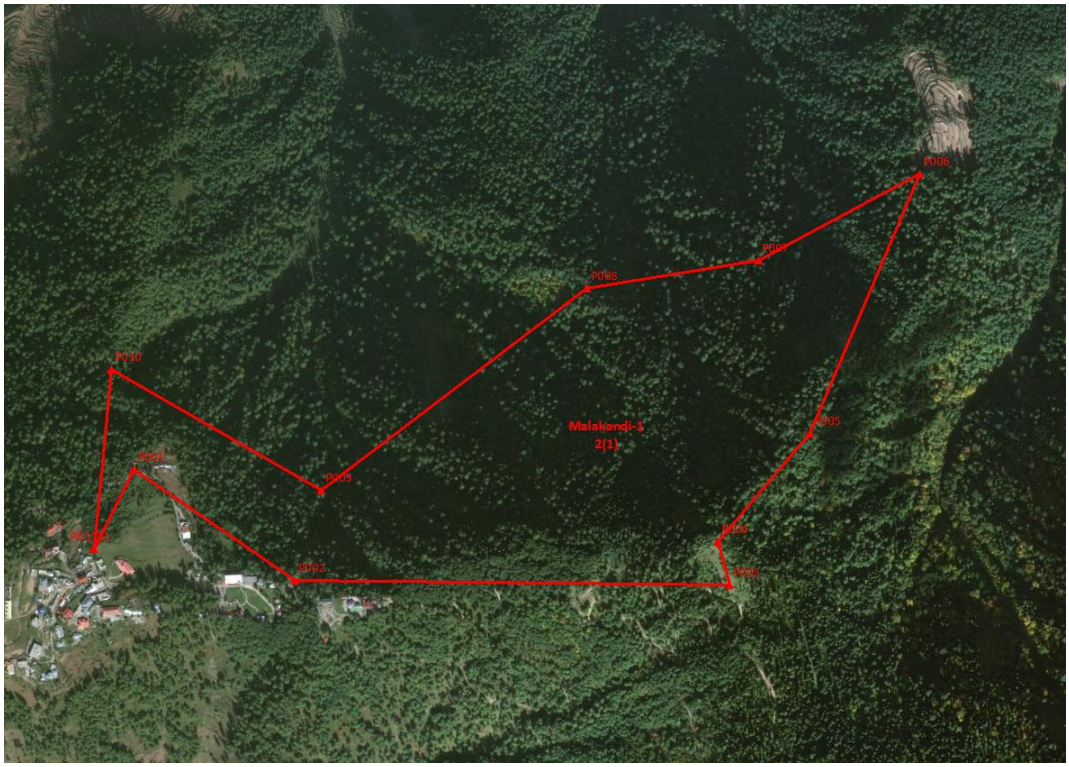


Figure 30 Map of surveyed boundary of Malakandi Forest Compartments 2(1), Kaghan Forest Division, Manshera, KP

Compartment 9 Manshera, KP

Forest Name	Khandheri
Compartment	8(1)
Forest Sub-Division	Shinkiari
Division	Siran
Village/Settlement	Khandheri
District	Manshera
Province	Khyber Pakhtunkhwa
Area (Ha)	29.96
No. of Pillars	12

PointId	Latitude	Longitude	Height	Description	Pillar Conditions
P001	34.47654	73.29151	1186.78	Natural ground	Nonexistent
P002	34.47624	73.29295	1241.985	Natural ground	Nonexistent
P003	34.47668	73.2942	1281.324	Natural ground	Nonexistent
P004	34.47642	73.29616	1342.382	Natural ground	Nonexistent
P005	34.4771	73.2985	1403.872	Natural ground	Nonexistent
P006	34.47716	73.30136	1475.296	Natural ground	Nonexistent
P007	34.47776	73.3039	1436.191	Natural ground	Nonexistent
P008	34.47982	73.30307	1367.431	Natural ground	Nonexistent
P009	34.47964	73.29867	1293.001	Natural ground	Nonexistent
P010	34.47931	73.29583	1196.664	Along road/No boundary pillar	Nonexistent
P011	34.47899	73.29289	1143.107	Turning point/No Pillar	Nonexistent
P012	34.47838	73.29258	1151.875	Concrete pillar	Good

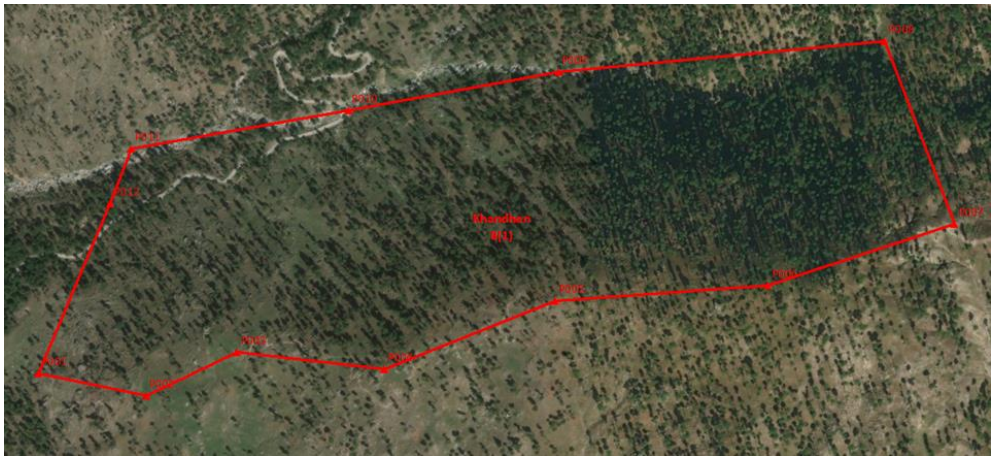


Figure 31 Map of surveyed boundary of Khandheri Forest Compartments 8(1), Siran Forest Division, Manshera, KP-.

Limitations

The piloting of forest boundary survey and mapping was done primarily to define a robust methodology for compartmentalizing the forested areas and demarcate their legal boundaries. Such legal boundaries are required for REDD+ related monitoring activities at the provincial levels. This piloting study had several limitations including the understanding of the scope of works, lack of highly accurate devices, difficulty in terrain and accessibility and other practical issues during the undertaking of the pilot. Major limitations during the pilot were:

- Use of single frequency L1 Differential GPS instead of dual L1/L2 frequency DGPS, thus limiting the accuracy levels of positioning of the forest boundary pillars/markers. The achievable accuracy using L1/L2 DGPS is within 5-10 cm in horizontal.
- Due to the limitation of time, piloting was done in sub-tropical forests of Punjab and KP in limited number of districts.
- Identification of forest boundaries where boundary pillars/markers were not established was difficult even for the local forest ranger. This may have attributed to non-identification of few boundary markers and thus may have caused some errors in boundary demarcation.
- Due to non-availability of legal property Massavi Maps and Forest History Files, validation of the surveyed boundaries could not be done against the legal documents.

These limitations are the lesson learned during the pilot and should be taken into account while upscaling the process for boundary demarcation in the provinces.

Methodological Guideline

Based on the methodological approach developed and the piloting exercise undertaken, following methodological guideline is proposed for identifying, surveying, delineating and mapping of the forest compartment boundaries for the purpose of forest management and REDD+ related forest monitoring for the provincial levels MMRV. The recommended guidelines are:

Preparation for the boundary survey and demarcation by collecting and reviewing existing Massavi Maps, Forest History Files and other reference secondary information.

1. Planning of field survey using very high-resolution satellite imagery and/or Google Earth imagery.
2. Training of field survey crew on using dual frequency L1/L2 DGPS equipment for surveying and data post-processing in the field office.

3. Field survey planning in discussion with the district forest office and forest division/sub-division technical personnel.
4. Forest boundary field survey and demarcation using dual frequency L1/L2 DGPS.
5. Inventory of existing boundary pillars.
6. Boundary concrete pillar repair and /or new installation and documentation.
7. DGPS data post-processing and boundary GIS data creation with relevant attributes.
8. Verification of boundary by district forest officer.
9. Update/revision of boundary map, if necessary.
10. Certification/endorsement of the demarcated boundaries.
11. Integration of boundary data in the Provincial Forest Monitoring System and National Forest Monitoring System.