Republic of Mozambique

Ministry of Land, Environment and Rural Development

National Directorate of Forests

THE REPUBLIC OF MOZAMBIQUE

THE PROJECT FOR THE ESTABLISHMENT OF SUSTAINABLE FOREST RESOURCE INFORMATION PLATFORM FOR MONITORING REDD+

Final Report (Summary)

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Acronyms

AIFM	Integrated Assessment of Land and Forests
AFD	French Development Agency
AGB	Above Ground Biomass
ALOS	Advanced Land Observing Satellite
ANAC	Nacional Administration of Conservation Areas
AVNIR-2	Advanced Visible and Near Infrared Radiometer-2
AQUA	National Agency for Environmental Quality Control
BA	Burned Area
BCEF	Biomass Conversion and Expansion Factor
BGB	Below Ground Biomass
BUR	Biennial Update Report
C/P	Counter Part
CDS	Centre for Sustainable Development
CENACARTA	National Centre of Cartography and Remote Sensing
DBH	Diameter Breast Height
DINAB	National Directorate of Environment
DINAGECA	National Directorate of Geography and Cadaster
DINAF	National Directorate of Forests
DINAT	National Directorate of Lands
DFRI/DIRF	Department of Forest Resources Inventory
DNRI/DIRN	Department of Natural Resources Inventory
DNTF	National Directorate of Lands and Forests
DPTADER	Provincial Department of Land, Environment and Rural Development
FCPF	Forest Carbon Partnership Facility
FNDS	National Fund for Sustainable Development
FREL/FRL	Forest Reference Emission Level/ Forest Reference Level
GBFM	Ground-Based Forest Monitoring
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
GPS	Global Positioning System
GT	Ground Truth
IGN FI	National Institute of Geographic and Forest Information France International
IIAM	Mozambique Institute for Agrarian Research
IIED	International Institute for Environment and Development
IND	National Demining Institute
INTIC	National Institute for Information Technology and Communication
JAXA	Japan Aerospace Exploration Agency
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
JJ-FAST	JICA-JAXA Forest Early Warning System in the Tropics
MASA	Ministry of Agriculture and Food Securtiy
MCA	Millennium Challenge Account
MICOA	Ministry of Coordination of Environmental Affairs
MINAG	Ministry of Agriculture
MITADER	Ministry of Land, Environment and Rural Development
MODIS	Moderate Resolution Imaging Spectroradiometer
M & MRV	Monitoring & Measurement, Reporting and Verification
MRV	Measurement, Reporting and Verification
NFI	National Forest Inventory

NGO	**Non-Governmental Organization**
OJT	**On-the-Job Training**
PALSAR	**Phased Array Type L-band Synthetic Aperture Radar**
PaMs	**Policy and Measures**
PEDSA	**Strategic Plan for Sustainable Development of Agriculture**
QA/QC	**Quality Assurance/Quality Control**
RD	**Record of Discussion**
REL/RL	**Reference Emission Level/ Reference Level**
R-PP	**Readiness Preparation Proposal**
SADC	**Southern African Development Community**
SAR	**Synthetic Aperture Radar**
SBSTA	**Subsidiary Body for Scientific and Technological Advice**
SDAE	**Services for Economic Activities**
SPF	**Provincial Service of Forest**
SPFFB	**Provincial Service of Forest and Wildlife**
SPGC	**Provincial Service of Geography and Cadaster**
SPOT	**Satellite Pour l'Observation de la Terre**
TWG	**Technical Working Group**
UEM	**Eduardo Mondlane University**
UNFCCC	**United Nations Framework Convention on Climate Change**
UPG	**Pedagogic University**
USAID	**United States Agency for International Development**
UT-REDD+	**REDD+ Technical Unit**
WB	**World Bank**
ZAE	**Agroecological Zoning**

1 Overview of the Project

1.1 Background

In the Republic of Mozambique, while roughly 50% of the land mass or approximately 39 million hectares is covered by forests. But now deforestation is advancing in the country, particularly over the five-year period since 2006, which saw an average annual deforestation rate of approximately 0.53%, higher than in any previous five-year period. The main reasons for this deforestation include charcoal production, mining development, excessive use of shifting cultivation, conversion to agricultural land and illegal logging.

On the other hand, importance of functions of forest is increasing in the countermeasure of climate change and deforestation and forest degradation and preventing greenhouse-gas emissions and increasing their removal (called reducing emissions from deforestation and forest degradation, or REDD+) is decided as one mechanism based on Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC).

In light of such conditions, Mozambique is proactively advancing activities toward implementation of REDD+. Mozambique's aim behind these efforts is to utilize REDD+ to make progress on realizing a balance between sustainable economic growth and forest conservation.

However, with regard to monitoring, measurement, reporting and verification (M & MRV) of REDD +, the capacity of staff of DINAF was limited, and renewal of forest information at the national level was not systematized. It was also needed to improve the skills and knowledge of the staff concerning methods of satellite imagery analysis and forest inventory which are necessary to study information of extensive forest resource in Mozambique. Furthermore, it was difficult to acquire other knowledge and skills necessary for MRV of REDD +, such as FREL / FRL setting, biomass and carbon estimation method.

Based on the above background, DINAF of MITADER and JICA collaborated to implement "the Project for the Establishment of Sustainable Forest Resource Information Platform for Monitoring REDD + in the Republic of Mozambique " (hereinafter referred to as "the Project").

1.2 Structure and Overall Picture of the Outputs of the Project

The structure of the Project that summarizes the project purpose, overall goal, outputs, etc. is shown below.

Table 1.1 Structure of the Project

Overall goal: Establishing sustainable forest management and the preparatory system for REDD+ throughout Mozambique, based on information obtainable from the forest resource information platform.
Project purpose: Periodically and appropriately implementing forest resource monitoring based on the forest resource information platform management plan.
Outputs: Output 1: Database System functioning as the Forest Resource Information Platform is established. Output 2: Basis of MRV for the Forest Resource Information Platform is developed. Output 3: RELs/RLs for the Forest Resource Information Platform are created. Output 4: Data set of biomass and carbon estimate is prepared.
Project period: April 2013 – March 2018 (five years)

Project subject region: Base: Maputo Pilot provinces: Gaza and Cabo Delgado (which include typical Mozambique vegetation) Subject region of forest resource information platform database: nationwide
Counterparts (C/P) agency: National Directorate of Forests (DINAF), Ministry of Land, Environment and Rural Development (MITADER)

The overall picture of the outputs of the Project is shown in the Figure 1.1 below.

Figure 1.1 Overall Picture of the Outputs of the Project

In this summary, the activities implemented and outputs of each field, which is 1) Forest Resource Information Platform, 2) Remote Sensing, 3) Forest Inventory, 4) Biomass Estimation, 5) FRL Development, is described as follows,

2 Development of Forest Resource Information Platform

2.1 Objectives of the Forest Resource Information Platform

The forest resource information platform is developed as the database system to enable the centrally management and sharing of information and data on forest, forestry and the related issues, and providing functions of searching, perusing and renewing them, with the overall objectives of contribute promoting REDD+ and developing sustainable forest management. Based on the objectives, six specific objectives shown in Figure.2.1. are set keeping in mind the outputs, namely what the platform is used for.

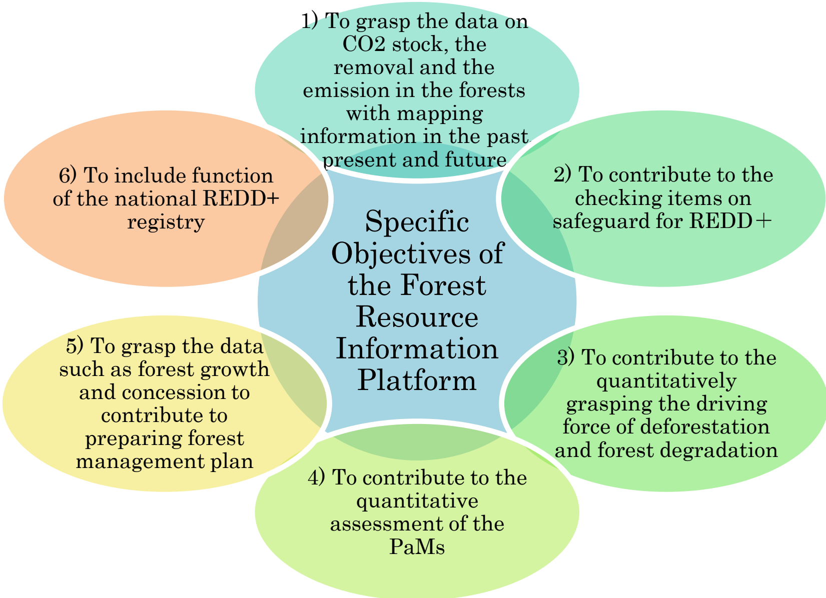


Figure 2.1 Specific Objectives of the Forest Resource Information Platform

2.2 Structure of the Forest Resource Information Platform

Based on the specific six objectives, the platform has the eight components specified in Figure.2.2.

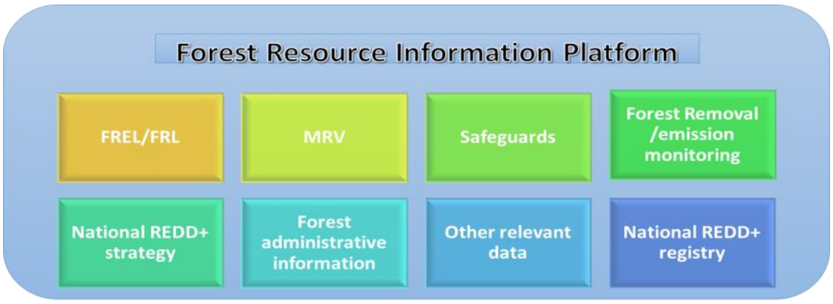


Figure 2.2 Component of the Forest Resource Information Platform

2.3 Function of the forest resource information platform

The forest resource information platform provides mainly three functions shown in Fig.2.3.

・Provision of the information related to REDD+

・Visualization of land use/land cover on the map

・Estimation of the Emission and analysis of the forest inventory survey results

Figure 2.3 Outline of the Platform Function

The information related to REDD+ is provided for each of the eight components shown in Table 2.1.

Table 2.1 Outline of information provided from the forest resource information platform

Compornent	Outline of information provided
FREL/FRL	• FREL/FRL to estimate the emissions reduction to be achieved through the REDD+ activities is shown. • All the elements relating activity data, emission factors and estimations of emission amount used for setting FREL/FRL are clearly shown.
MRV	• Concept and plans on what and how Mozambique measure, report and verify with respect to REDD+ are shown.
Safeguards	• Information as to how safeguards were handled and respected through the REDD+ activities is provided through the safeguard information system.
Removal/Emissions Monitoring	• Trends of forest carbon stock, removal, and emissions are shown.
National REDD+ Strategy	• Information concerning the National REDD+ Strategy is provided. • Legal information related to forest management and REDD + etc. is provided. • Quantitative evaluation of the policy and measures (PaMs) is shown.
National REDD+ Registry	• Information concerning REDD+ projects applied and approved in accordance with the Decree on Rules for Procedures to Approve Projects of REDD+ is shown, e.g. Project name, Activity type, Area of implementation, Shape file on project area, Date of start and end of the project, Target emission reduction and removal increase amount (CO2t), and Actual emission reduction and removal increase amount (CO2t).
Forest Administrative Data	• Information on forest administration such as Forest management organization structures, promotion structure of REDD+ and concession is provided.
Other Relevant Data	• Other Relevant Data are provided. Other relevant data such as map data (e.g. road data, river data, and administrative boundary data) are provided.

The forest resource information platform is published on the Internet from the following URL.

URL : http://www.dinaf.gov.mz/pirf_mreddplus/

2.4 Action Plan for Utilization of the Forest Resources Information Platform

It was set as the action plan for utilization of the forest resource information platform by formulating the roadmap for the improvement of function of the platform and the roadmap for the updating of data and information.

In the roadmap for the improvement of function of the platform, 1) the content of the function, 2) the user of function, and 3) the improvement time were arranged by the function to be improved.

Regarding the users of functions, the information provided from the forest resource information platform is divided into information that can be accessed in public and information that can be accessed only by stakeholders such as inside DINAF. Since usage method, requested function, access method are different depending on users, they are clarified.

The improvement time is roughly aligned with the roadmap for the updating of data and information, but it may be affected by the progress of other projects etc.

The roadmap for the updating of data and information consists of 1) statistics, 2) laws and regulations, 3) project registry, 4) activity data, 5) land cover/land use, 6) forest degradation, 7) deforestation, 8) forest inventory, 9) permanent plot, 10) FREL, 11) forest concession, 12) tree plantation, 13) safeguard, 14) MozFIP, 15) SUSTENTA project related information. 1) contents of information/data 2) the timing of firstly uploading to the platform, 3) data/information update frequency, 4) information format, 5) responsibile organization for creation/upload of data/information, etc, are arranged by each information/data mentioned above.

2.5 Capacity Building for Forest Resource Information Platform

For the forest resource information platform, capacity building focused on "Strategic information planning" and "Operation and maintenance" has been conducted by (1) on-the-job training in the process of discussing data to be handled and functions in the forest resource information platform at the technical working groups, (2) presentation on the forest resource information platform by CPs themselves at the workshop for the report or the meetings with other organization and (3) lecture and exercise to update the contents and maps in the forest information platform.

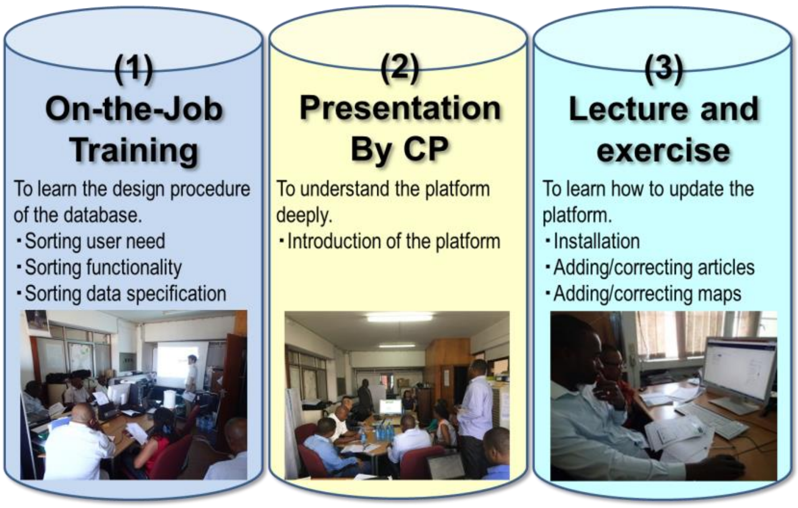


Figure 2.4 Capacity Building Program for Forest Resource Information Platform

3 Remote Sensing Analysis

3.1 Forest Cover and Land Use Map Development

Forest cover and land use maps (forest cover maps) for the Cabo Delgado and Gaza Provinces were developed using 2008 ALOS AVNIR-2 images. Main activities include:

1) Examination of classification classes with reference to the past projects
2) Supervised object-based classification with training data from initial ground truth surveys
3) Verification of initial classification results during the following ground truth surveys
4) Correction of errors by visual interpretation to improve the classification accuracy

(Semi-) evergreen closed forest	
(Semi-) evergreen open forest	
Mecrusse	
Mangrove	
(Semi-) deciduous closed forest (incl. Miombo dense)	
(Semi-) deciduous open forest (incl. Miombo open)	
Mopane	
Thickets	
Non-Forest Woodland and Grasslands (inc. Shrublands)	
Aquatic grasslands (inc. Aquatic shrublands)	
Tree crops	
Field crops	
Bare areas	
Settlements	
Water bodies	

Figure 3.1 Classification Classes

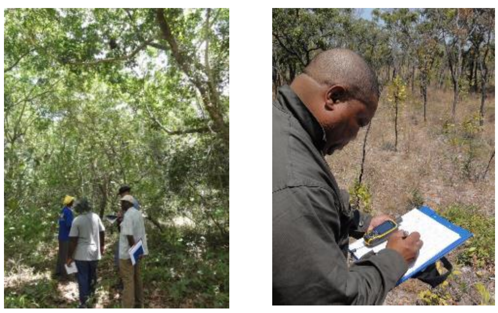


Figure 3.2 Ground Truth Survey

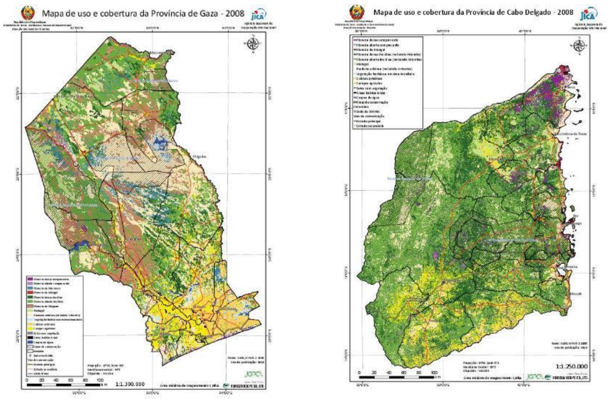


Figure 3.3 Forest Cover Maps for Cabo Delgado and Gaza Provinces,2008

These maps are the first 1/200,000 scale maps for the provinces and are used as base for the development of reference year maps and the REL setting. They are expected to be used for the sustainable forest management in the future.

3.2 Development of Reference Year Map

Using the 2008 forest cover map as a base (the 2008 base map) and time-series Landsat images, forest cover maps for the reference years (reference year maps) of 2002, 2005, 2010 and 2013 are developed to analyze the historical trend of forest cover changes in Cabo Delgado and Gaza Provinces. As a result, Activity Data (AD) necessary for the FREL and FRL setting are finally established. Figure 3.2 shows Workflow to develop Reference Year Map.

1) Landsat images for two consecutive reference points are compared to detect change areas.
2) Detected change areas are classified by change patterns to prepare change area maps.
3) Change area maps are superposed on the 2008 base map to prepare reference year maps.

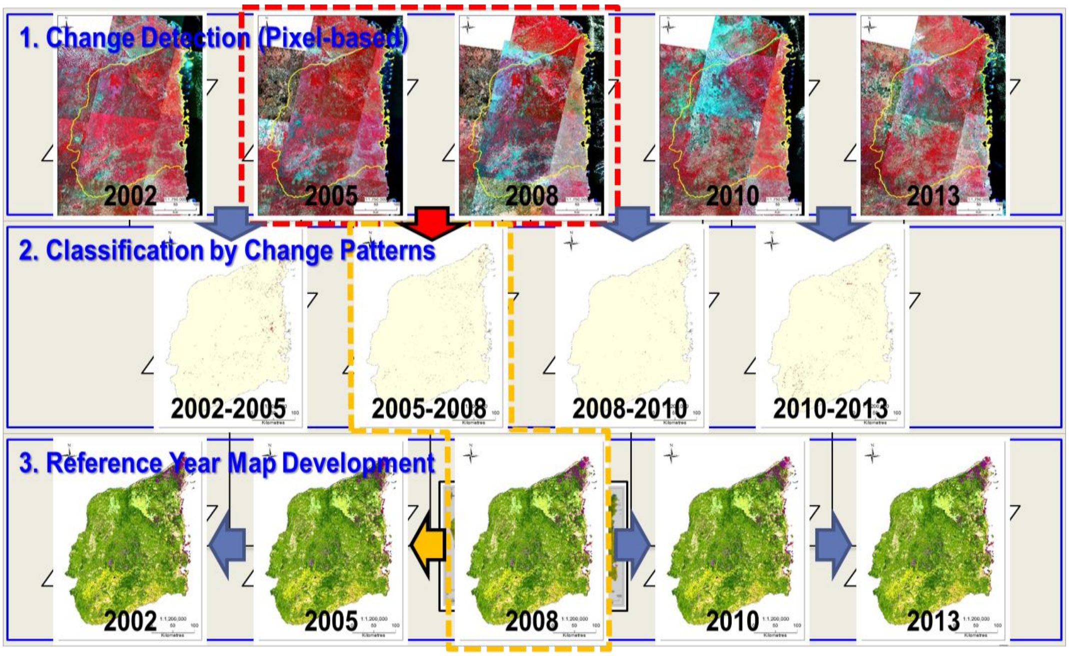
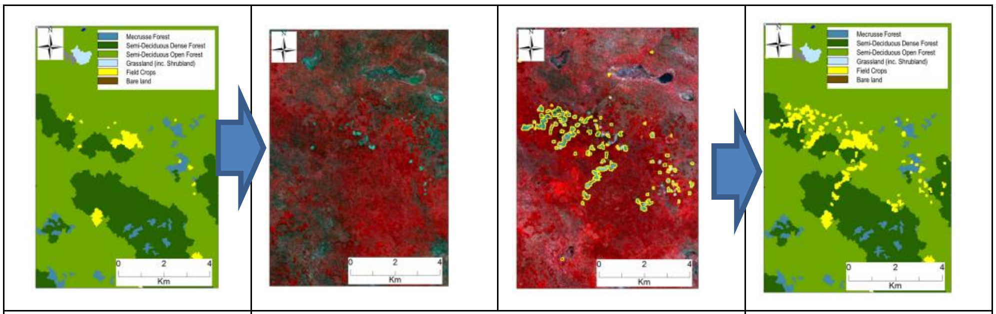


Figure 3.4 Workflow to Develop Reference Year Maps



2008 forest base map	Comparison of satellite images in 2008 (left) and a reference year (right)	Reference year forest cover map

Figure 3.5 Example of the Reference Year Map Development

3.3 Forest Cover Change Monitoring using Radar Images

The outline of the forest cover change monitoring using radar images (radar monitoring), a part of the NFMS, is shown in the following table.

Table 3.1 The outline of the forest cover change monitoring using radar images (radar monitoring)

Item	Descriptions
Main Objectives	➢ Detecting deforestation areas and estimating deforestation area. Furthermore, selecting an area where priority is given to deforestation measures by complex analysis adding layer of the forest cover map, road map, inclination information of the topography, etc. ➢ Controlling deforestation caused by shifting cultivation by slash-and-burn farming by monitoring and countermeasures in mainly buffer zones to be set at sites where deforestation occurs. ➢ Utilizing newsletters (public relations magazine) to communicate the current conditions of deforestation to residents, and reporting the necessity of measures to reduce deforest to policy makers
Target area	Whole of Mozambique
Satellite image	ALOS-2/PALSAR-2 (25m resolution)
Observation season	Mainly from July to September
Observation period	Once a year
Minimum area	1 ha

Using ALOS-2/PALSAR-2 images, preliminary radar image analysis for the detection of deforestation areas was conducted, and the following analysis method was developed.

1) Obtaining the radar image of two-time points covering the target area.

2) Calculating the difference of the backscatter coefficients between radar images at two-time points.

3) As deforestation area, extracting the area with the difference below the threshold obtained by referring to the field survey result.

Figure 3.6 shows the distribution of differences between two backscatter coefficients calculated from radar images at two different time points.

If the difference is greater than the threshold indicated by the red line and the backscatter coefficient at the beginning (Before tree loss in the figure) is -18 dB or more (if it falls within the framework of the yellow-green area denoted as deforestation area), that area is regarded as deforestation. In addition, when the backscatter coefficient at the beginning is less than -18 dB, since it is non-forest from the beginning, it is not regarded as deforestation regardless of the size of difference (if it falls within the framework of the gray area indicated as non-forest area). The field verification result shown in Figure 3.6 shows that nearly all deforested areas can be detected by using the created red line threshold.

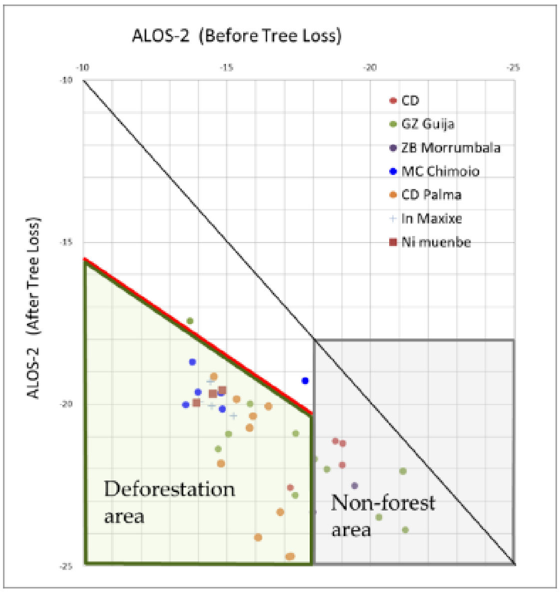


Figure 3.6 Threshold of deforestation extraction by difference of backscatter coefficients between two-time points

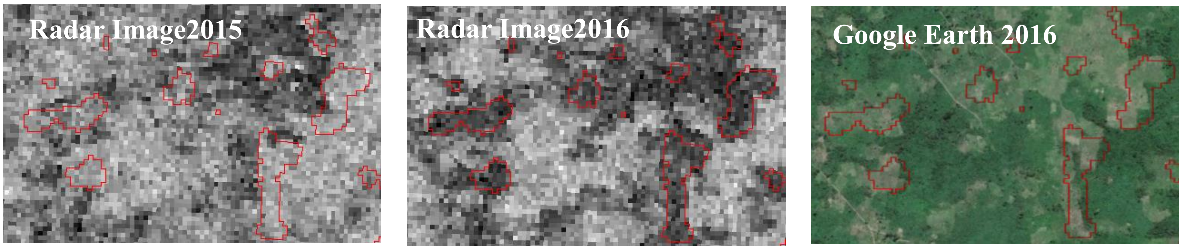


Figure 3.7 Example of deforestation area (area of red polygon) extracted using threshold

3.4 Capacity Building Program for Technical

The remote sensing capacity building program consists of (1) lectures and exercises to transfer new knowledge and techniques, (2) on-the-job training, including ground truth surveys and image analysis and interpretation, as a part of the actual project activities, and (3) technical working groups to discuss specifications and analysis results. The program covers various activities such as forest cover map development, forest cover change detection and reference year map development, and forest cover change monitoring using radar images.

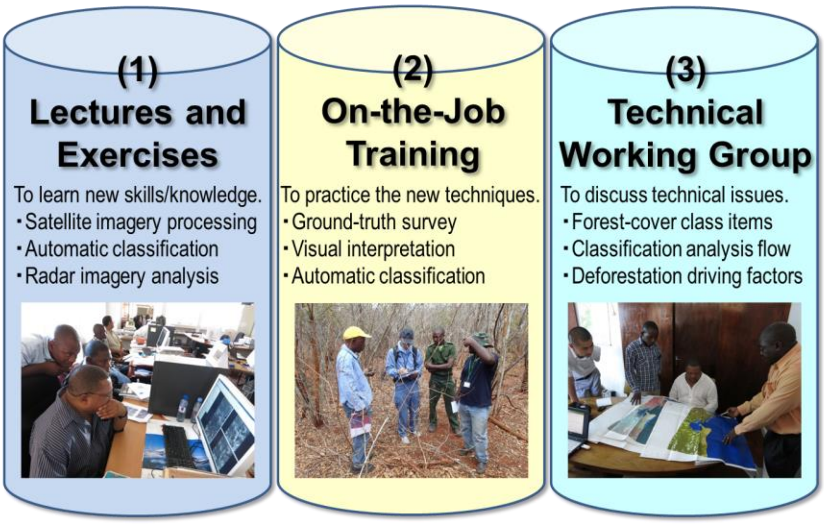


Figure 3.8 Capacity Building Program for Remote Sensing

4 Forest Inventory

4.1 Concept of forestry inventory of the Project

Objectives of the system for forest inventory to be developed in the Project are to calculate emissions factor, which is one of elements for estimating emissions from deforestation and forest degradation and removal from activities such as afforestation in REDD+ activities, not just to aid in formulating sustainable forest plans for the future through ascertaining forest stock by forest type per unit area in Mozambique. In developing this forest inventory system, it is essential to study a variety of methodologies referring to past cases in Mozambique and to design simple, efficient and sustainable methods taking into consideration Mozambique's implementation capacity.

4.2 Method of forest inventory

(1) Calculation and distribution of the required number of clusters

1) Method of calculating the required number of clusters

The clusters were set up, using stratified random sampling method and the required number of clusters for each stratified forest layer was calculated using the sampling program by Winrock.

2) Selection method of survey point

A grid with 1 km interval was drawn on the forest cover map and topographical map of the study area using ArcGIS. Then, by the stratified random sampling method, clusters corresponding to the required number of clusters were selected on intersections of the grid at random as the Priority clusters. Moreover, the Supplementary clusters which are as many as the Priority clusters were selected on intersections of the grid at random.

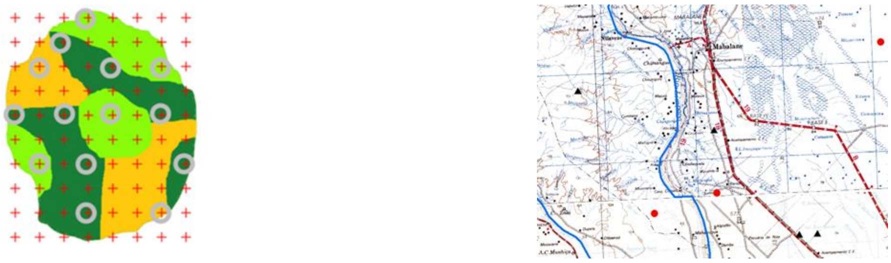


Figure 4.1 Image of stratified random sampling and Clusters location map
(●= Priority cluster, ▲= Supplementary cluster)

(2) Shape of cluster and plot

A square of 100m x 100m was adopted as the shape of a cluster. The four corners of a cluster were plot starting points. Then, the plot No.1 was set at the southwest corner of a cluster and the plots from No.2 to No.4 were set in a clockwise direction in a cluster. The shapes of a plot were in two patterns. One was in the rectangular shape (50m x 20m) applied to all forest types excluding mangrove forests and the other was in the circular shape (radius: 17.84m) applied to mangrove forests.

Specification of plot shape

Item	Shape	Size (Area)
Cluster	Square	100 m x 100 m
Plot	Rectangular	50 m x 20 m (1,000 m^2)
Subplot	Rectangular	25 m x 10 m (250 m^2)
Plot	Circular	Radius r = 17.84 m (999.9 m^2)
Subplot	Circular	Radius r = 8.92 m (250 m^2)

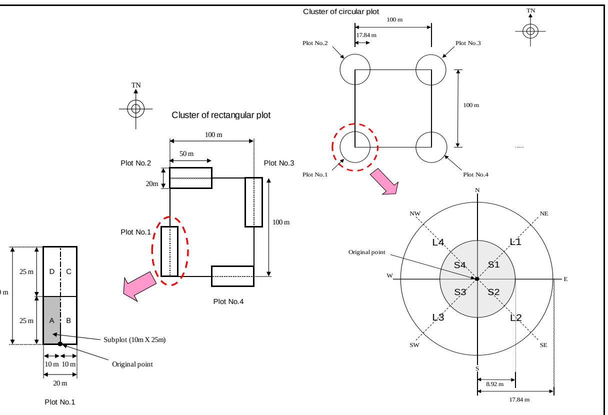


Figure 4.2 Shape of cluster and plot

4.3 Results of inventory

Results of inventory in Cabo Delgado and Gaza provinces are shown below.

Table 4.1 Results of inventory in Gaza

Forest type	Number of plots	Area(ha)	Number of trees/ha (trees/ha)	Total number of trees (1,000trees)	Basal area/ha (m^2/ha)	Commercial volume/ha (m^3/ha)	Total Commercial Volume(m^3)	Stem volume/ha (m^3/ha)	Total Stem Volume(m^3)
(Semi-) evergreen forest	76	142,082	322	45,750	6.98	15.39	2,187,068.23	40.10	5,696,919.87
Mecrusse	123	291,616	1,332	388,433	17.87	32.87	9,586,584.38	75.01	21,872,949.70
Mangrove	0	291	0	0	0.00	0.00	0.00	0.00	0.00
(Semi-) deciduous forest (incl. Miombo)	339	2,545,795	418	1,064,142	6.80	12.97	33,016,415.36	33.78	85,996,955.10
Mopane	138	1,073,261	449	481,894	4.97	8.78	9,426,451.36	20.87	22,397,883.81
Total	676	4,053,045	489	1,980,219	7.12	13.38	54,216,519.33	33.55	135,964,708.48

Table 4.2 Results of inventory in Cabo Delgado

Forest type	Number of plots	Area(ha)	Number of trees/ha (trees/ha)	Total number of trees (1,000trees)	Basal area/ha (m^2/ha)	Commercial volume/ha (m^3/ha)	Total Commercial Volume(m^3)	Stem volume/ha (m^3/ha)	Total Stem Volume(m^3)
(Semi-) evergreen forest	180	365,682	540	197,468	12.26	44.24	16,175,943.27	92.04	33,655,908.55
Mecrusse	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Mangrove	135	31,412	1,636	51,390	16.20	35.16	1,104,571.57	68.98	2,166,736.94
(Semi-) deciduous forest (incl. Miombo)	753	5,287,878	385	2,035,833	9.95	34.22	180,935,321.53	71.71	379,172,579.87
Mopane	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Total	1,068	5,684,972	402	2,284,691	10.13	34.87	198,215,836.36	73.00	414,995,225.36

1. The mangrove forest survey was not carried out in Gaza province. Sampling plots of the inventory survey was designed for the integrated area of Gaza and Cabo Delgado provinces. As a result of extracting samples by the stratified random sampling method, samples plots were not extracted from Mangrove forests in Gaza province.
2. The number of plots is based on the plots identified as forest of each forest type in the forest cover/land use map 2013.

4.4 Photograph of each forest type and inventory implementation

Semi-evergreen forest (Cabo Delgado province)

Mecrusse forest (Gaza province)

Semi-deciduous forest (Cabo Delgado province)

Mopane forest (Gaza province)

Mangrove forest (Cabo Delgado province)

Inventory implementation (Cabo Delgado province)

Inventory implementation (Cabo Delgado province)

Inventory implementation (Cabo Delgado province)

Figure 4.3 Photograph of each forest type and inventory implementation

4.5 Capacity Building Program for Forest Inventory

For forest inventory, capacity building was promoted as follows. (1) Conducting the basic forest inventory training to let DIRF and SPF staff learn how to implement the forest inventory using several measuring instruments improved. (2) Conducting the QA/QC training. The lectures were given on knowledge of QA/QC for verifying the accuracy of the forest inventory survey and improving the accuracy and the method of inventory. (3) Providing OJT through implementing forest inventory, by the supervision of the inventory by the subcontractor.

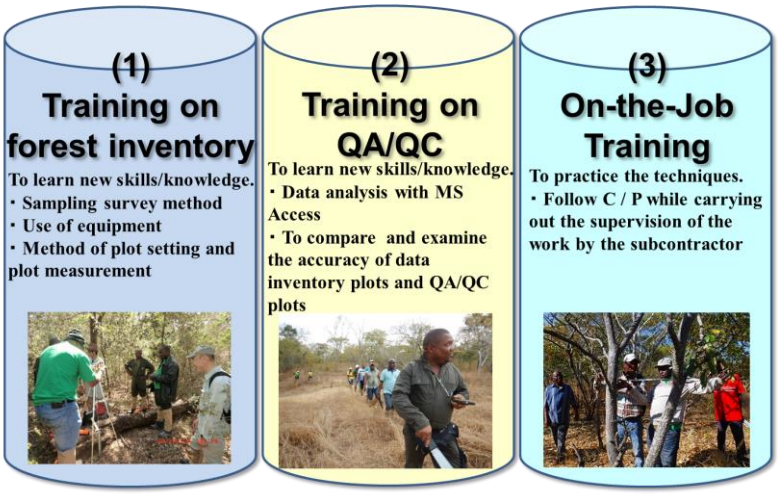


Figure 4.4 Capacity Building Program for Forest Inventory

5 Biomass Estimation

5.1 Biomass Survey

The Project implemented a biomass survey in Mopane forests in 2016 in Massangena District, Gaza Province for the purpose of developing allometric equations to estimate biomass of Mopane trees. Allometric equations for estimating the below ground biomass (BGB) of evergreen forests, mopane forests and mangrove forests could not be found in Mozambique and then, it was decided to implement a biomass survey for one of these forest types. Mopane forests were then selected as they cover the largest area among these forest types and are considered an important forest type in Mozambique. As a result of the survey, an allometric equation for estimating the above ground biomass (AGB) as well as BGB was developed; the former was used to compare its result with that of the allometric equation already developed in Mozambique. The former was decided as a more suitable allometric equation as a result of comparing with the existing allometric equation in Mozambique. Therefore, it was used to calculate AGB of Mopane forests in the Project.

(1) Method of the survey

The biomass survey followed the procedure described below.

1) Measurement of sample trees in the field

a. Selecting the sample trees of each diameter class

b. Measuring the height, DBH, etc. of each sample tree

c. Setting the area to be excavated

2） Destructive sampling survey on the field

a. Digging up the soil around the sample tree and its lateral roots; collecting the root pieces

b. Felling the sample tree (by pushing the stem using the arm of an excavator)

c. Dividing the felled sample tree into 4 parts (stem, branches, leaves and roots)

d. Measuring the total fresh weight of each part (measuring for the stem in the photo)

e. Extracting the subsamples from each part; measuring the fresh weight of each subsample piece

3) Measurement of the dry weight : Drying the subsamples of each part completely in the drying oven and measure their weight.

4) Analysis of the result of measurement:

a. Estimating total dry weight (biomass) of each sample tree

Total Dry Weight = Total Fresh Weight x Subsample Dry Weight / Subsample Fresh Weight

b. Making regression analysis to find relationship between the DBH, tree height and its biomass.

(2) Result

1) Result of measurement of fresh weight and dry weight of sample trees

The data collected in the field on each sample tree (DBH, height and total fresh weight) and the total dry weight estimated are shown in the Table 5.1.

Table 5.1 Data of the sample trees

No.	DBH (cm)	Height (m)	Total Fresh Weight (kg)					Total Dry Weight Estimated (kg)				
			Stem	Branches	Leaves	AG Total	Roots	Stem	Branches	Leaves	AG Total	Roots
1	5.0	4.7	4.3	2.3	0.8	7.3	4.5	2.8	1.4	0.5	4.7	3.0
2	8.0	6.9	17.2	4.8	2.5	24.4	18.4	11.4	2.9	1.3	15.6	11.4
3	17.0	11.7	113.3	46.7	6.7	166.8	46.9	82.1	30.3	3.4	115.8	29.9
4	21.0	12.8	189.1	17.3	6.3	212.6	61.8	139.6	11.3	3.3	154.1	41.2
5	24.5	13.7	318.5	173.7	18.7	510.9	164.2	249.4	125.9	9.6	384.9	101.1

No.	DBH (cm)	Height (m)	Total Fresh Weight (kg)					Total Dry Weight Estimated (kg)				
			Stem	Branches	Leaves	AG Total	Roots	Stem	Branches	Leaves	AG Total	Roots
6	31.0	16.7	631.6	299.4	14.7	945.7	242.2	473.0	200.7	8.7	682.4	155.9
7	33.5	14.2	568.3	468.7	22.7	1,059.7	250.5	427.4	307.6	12.1	747.1	155.8
8	40.0	17.9	828.3	706.1	68.0	1,602.3	346.0	618.4	499.1	32.7	1,150.2	196.5
9	45.0	16.8	862.0	527.4	25.0	1,414.4	310.5	664.3	404.9	13.1	1,082.3	189.0
10	51.0	16.3	1,268.8	1,598.3	46.3	2,913.4	582.0	957.9	1,037.4	26.4	2,021.7	382.8
11	56.6	17.7	1,599.0	1,196.1	42.3	2,837.4	489.2	1,269.8	860.9	24.4	2,155.1	359.5
12	62.3	22.6	1,798.0	2,938.5	100.5	4,837.0	1,060.9	1,340.5	1,941.2	51.2	3,332.8	815.7
13	74.5	19.2	3,134.4	2,931.3	114.3	6,180.0	1,292.7	2,409.8	2,098.5	59.3	4,567.7	758.7
14	80.5	20.2	2,108.1	4,070.7	39.5	6,218.3	962.2	1,613.9	2,621.5	22.3	4,257.8	541.8
15	87.6	18.9	2,554.1	2,497.3	72.2	5,123.6	1,237.1	2,129.5	1,970.8	39.9	4,140.3	867.9
16	101.8	21.6	3,766.3	4,611.9	66.0	8,444.1	1,928.9	2,929.8	3,039.0	33.6	6,002.5	1,339.0
17	109.2	17.9	4,156.0	5,840.5	95.1	10,091.6	2,142.7	3,299.1	3,808.4	57.4	7,165.0	1,446.3

2) Regression analysis of the result of measurement

a. Development of an allometric equation for estimating above ground biomass
Regression analysis of 2 variables (DBH and tree height) on biomass was made. The regression model applied is "AGB (kg) = a * DBH (cm) ^ b * Height (m) ^ c". This model was converted to "Ln AGB (kg) = ln a + b * ln DBH (cm) + c * ln Height (m)".

Allometric equation: AGB (kg) = 0.03325*DBH^1.848*Height^1.241 R^2 = 0.9918

b. Development of an allometric equation for estimating below ground biomass
Regression analysis of 2 variables (DBH and tree height) on biomass was made. The regression model applied is "BGB (kg) = a * DBH (cm) ^ b * Height (m) ^ c". This model was converted to "Ln BGB (kg) = ln a + b * ln DBH (cm) + c * ln Height (m)".

Allometric equation: BGB (kg) = 0.09572*DBH^1.7969*Height^0.3797 R^2 = 0.9806

5.2 Allometric Equations to Estimate Biomass of Various Forest Types

The Project decided to estimate the biomass and carbon stocks of various forest types, using forest inventory data and allometric equations. For allometric equations, the Project first searched those already developed within the country. In fact, it was found the University of Eduardo Mondlane developed allometric equations for several forest types. For forest types for which no suitable allometric equation was developed within the country, the allometric equations developed in the neighboring countries with similar ecological conditions were searched. If suitable allometric equations cannot be found from neither Mozambique nor its neighboring countries, then the equations provided in the IPCC Guidelines 2006 were applied. The project also developed allometric equations for Mopane forests by implementing the biomass survey described above.

5.3 Capacity Building Program for Biomass and Carbon Stock Estimation

For biomass and carbon stock estimation, capacity building was promoted as follows. (1) Holding the seminar on biomass and carbon stock estimation. The seminar consisted of lectures and practices. The lectures were given on basic knowledge on carbon stock estimation, measurement procedure, cases of surveys carried out in other countries, etc. The participants also practiced developing allometric equations and calculating carbon stocks of given forests using sample data. (2) Providing OJT by implementing a biomass survey. During the biomass survey, technical guidance was given to them on how to carry out measurement in the field. (3) Holding technical working group meetings. Discussing various subjects in TWG meetings supported the counterpart personnel understand methods of biomass and carbon stock estimation and its relevant issues.

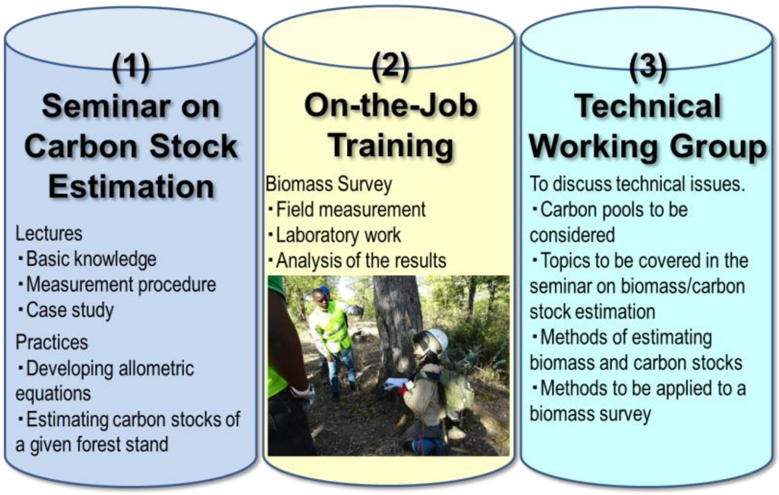


Figure 5.1 Capacity Building Program for Biomass and Carbon Stock Estimation

6 FRL Development

6.1 Method of developing FRELs/FRLs

The Project has drafted forest reference levels (FRLs) of Cabo Delgado and Gaza provinces according to a procedure illustrated in the framework given below.

Methods applied to development of the FRLs are summarized in Table 6.2 below.

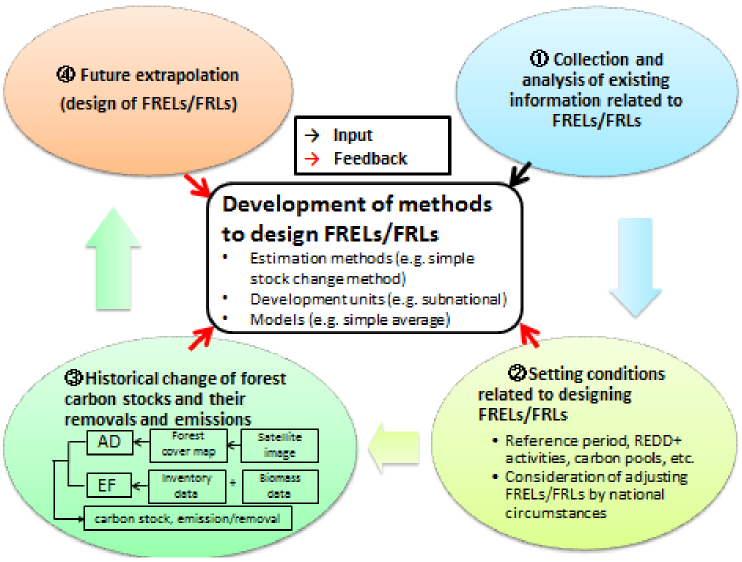


Figure 6.1 Workflow of developing FRLs

Table 6.1 Methods applied for the FRLs of Cabo Delgado and Gaza provinces

Features of FRLs	Adopted setting
REDD+ activities	Reducing emissions from deforestation; reducing emissions from forest degradation; enhancement of forest carbon stocks
Carbon pools	Above ground biomass(AGB); below ground biomass(BGB)

Reference period and the number of data points	Reference period: 2002 – 2013 The number of data points: 5 (2002, 2005, 2008, 2010, 2013)
Development of activity data (AD)	Analyzing changes of forest covers by using the ALOS and Landsat satellite images and developing forest area change matrices (as shown in Figure 6.2)
Development of emission factors (EF)	➢ Carbon stock of each forest type: based on forest inventory data (DBH, tree height) and allometric equations ➢ Carbon stocks of non-forest land cover: tentatively set as 0.
Levels of stratification	13 classes (5 forest classes; 8 non-forest classes)
Method of estimating future emissions/removals	Mean annual net emissions of the reference period
Adjustment of FRELs/FRLs by national circumstances	No adjustment made.

6.2 Estimation of Carbon Stocks and Emissions/Removals of Forests in the Past

The historical trends of carbon stocks and emissions and removals of forests were estimated separately for activity data (AD) and emission factor (EF) as follows,

1) AD

AD is the area changed from one land cover type to different land cover type between two-time points for the analysis. Time series analysis was conducted based on the reference year maps. Forest area change matrixes between each two-time points was created and the area of change between land cover types was estimated. (See Fig. 6.2 as an example)

AD: 2005 - 2008 (Unit：ha)			Term end													
			11	13	14	21	23	33	35	36	37	38	41	42	43	
			Evergreen Forest	Mecrusse Forest	Mangrove Forest	Deciduous Forest	Mopane Forest	Thicket	Grassland	Grassland Flood	Tree Crop Area	Field Crop	Bare Area	Village	Water Place	Total
Term Start	11	EvergreenForest	142,736	0	0	0	0	0	7	0	0	18	0	0	1	142,762
	13	Mecrusse Forest	0	292,377	0	0	0	8	81	0	13	407	1	0	1	292,888
	14	Mangrove Forest	0	0	291	0	0	0	0	0	0	0	0	0	0	291
	21	Deciduous Forest	1	0	0	2,556,864	100	26	429	7	86	1,633	10	93	3	2,559,252
	23	Mopane Forest	0	0	0	493	1,086,175	0	161	11	4	863	7	62	5	1,087,781
	33	Thicket	0	1	0	123	1	218,111	140	5	42	605	1	84	1	219,114
	35	Grassland	25	0	0	173	787	0	1,917,775	27	7	69	14	75	1,270	1,920,223
	36	Grassland Flood	0	0	0	0	0	0	0	115,979	0	0	0	0	0	115,979
	37	Tree Crop Area	0	0	0	1	0	0	11	0	404,489	21	0	132	0	404,654
	38	Field Crop	2	0	0	7	11	0	16	0	31	602,243	2	122	0	602,434
	41	Bare Area	461	2	0	70	51	0	227	22	7	90	52,166	3	1,053	54,154
	42	Village	0	0	0	5	0	0	13	0	0	9	0	60,450	0	60,478
	43	Water place	28	0	0	12	5	0	93	41	8	61	230	0	71,347	71,826
	Total		143,254	292,380	291	2,557,748	1,087,131	218,145	1,918,954	116,091	404,688	606,019	52,431	61,021	73,682	7,531,834

Figure 6.2 Example of Forest Area Change Matrix (Compared between year 2005 and 2008 in Gaza Province)

2) EF

EF was defined as the changed carbon stock per ha (increase or decrease) when a certain land cover type is converted to land cover type of different type. The average carbon stock per ha of each land cover type of forest and non-forest is shown in the table 6.2 below.

Table 6.2 Average Carbon Stock Per ha by Land Cover Type of Forest and Non-Forest

Carbon stock per ha of each forest type (CO2-ton/ha)			Carbon stock per ha of each non-forest type (CO2-ton/ha)		
Forest type	AGB	BGB	Non-Forest type	AGB	BGB
(Semi-) evergreen forest	156.43	45.01	Thicket	3.964	11.03
Mecrusse	113.12	8.48	Grassland	3.964	11.03
Mangrove	101.23	33.84	Grassland Flood	3.964	11.03
(Semi-) deciduous forest	35.88	12.15	Tree Crop Area	3.964	11.03
Mopane	275.26	114.27	Field Crop	0	0
			Grassland	0	0
			Village	0	0
			Water place	0	0

Based on the data in the Table 6.2, EF was set as a matrix as shown in Figre. 6.3.

EF (unit :CO_2-ton/ha)			Term end												
			11 Evergreen Forest	13 Mecrusse Forest	14 Mangrove Forest	21 Deciduous Forest	23 Mopane Forest	33 Thicket	35 Grassland	36 Grassland Flood	37 Tree Crop Area	38 Field Crop	41 Bare Area	42 Village	43 Water Place
Term start	11	EvergreenForest	0.00	-79.84	188.10	-66.37	-153.41	-186.45	-186.45	-186.45	-186.45	-201.44	-201.44	-201.44	-201.44
	13	Mecrusse Forest	79.84	0.00	267.93	13.47	-73.57	-106.61	-106.61	-106.61	-106.61	-121.60	-121.60	-121.60	-121.60
	14	Mangrove Forest	-188.10	-267.93	0.00	-254.46	-341.50	-374.54	-374.54	-374.54	-374.54	-389.53	-389.53	-389.53	-389.53
	21	Deciduous Forest	66.37	-13.47	254.46	0.00	-87.04	-120.08	-120.08	-120.08	-120.08	-135.07	-135.07	-135.07	-135.07
	23	Mopane Forest	153.41	73.57	341.50	87.04	0.00	-33.04	-33.04	-33.04	-33.04	-48.03	-48.03	-48.03	-48.03
	33	Thicket	186.45	106.61	374.54	120.08	33.04	0.00	0.00	0.00	0.00	-14.99	-14.99	-14.99	-14.99
	35	Grassland	186.45	106.61	374.54	120.08	33.04	0.00	0.00	0.00	0.00	-14.99	-14.99	-14.99	-14.99
	36	Grassland Flood	186.45	106.61	374.54	120.08	33.04	0.00	0.00	0.00	0.00	-14.99	-14.99	-14.99	-14.99
	37	Tree Crop Area	186.45	106.61	374.54	120.08	33.04	0.00	0.00	0.00	0.00	-14.99	-14.99	-14.99	-14.99
	38	Field Crop	201.44	121.60	389.53	135.07	48.03	14.99	14.99	14.99	14.99	0.00	0.00	0.00	0.00
	41	Bare Area	201.44	121.60	389.53	135.07	48.03	14.99	14.99	14.99	14.99	0.00	0.00	0.00	0.00
	42	Village	201.44	121.60	389.53	135.07	48.03	14.99	14.99	14.99	14.99	0.00	0.00	0.00	0.00
	43	Water place	201.44	121.60	389.53	135.07	48.03	14.99	14.99	14.99	14.99	0.00	0.00	0.00	0.00

Figure 6.3 Matrix of EF Showing Change of Carbon Stock Per ha Based on Change of Land Cover Type

6.3 Developing FRLs of Cabo Delgado and Gaza

Based on the method described above, mean annual net emissions for the reference period, which is forest reference level (FRL), were calculated. The FRLs for Cabo Delgado and Gaza provinces are 1,123,456 ton-CO2/yr. and 250,108 ton-CO2/yr. respectively.

Cabo Delgado Province:

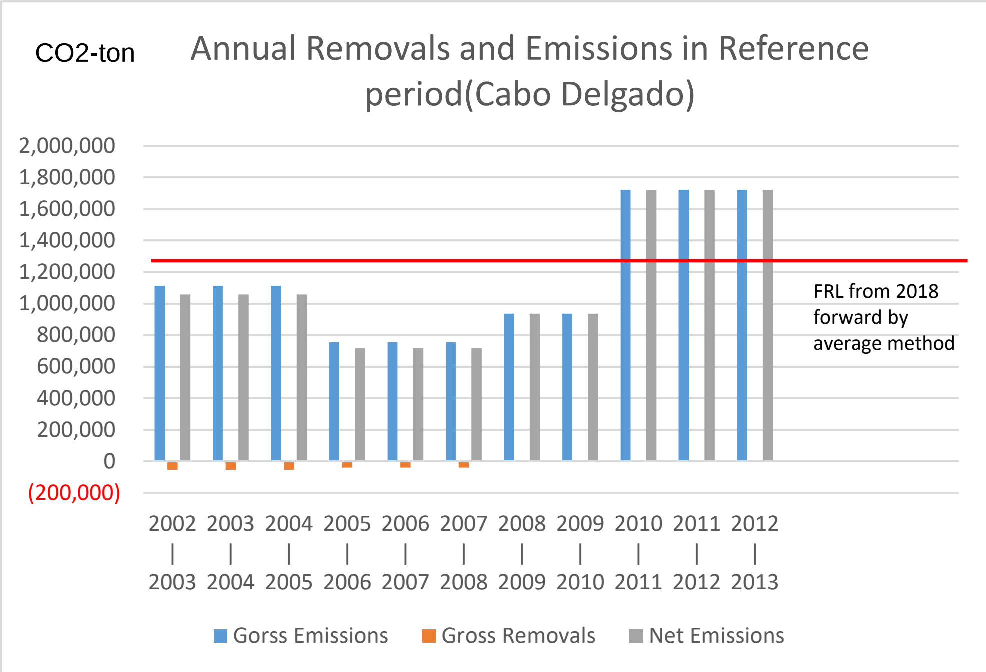


Figure 6.4 Emissions/removals of carbon stocks during the reference period (Cabo Delgado)

Table 6.3 Calculation of the mean annual net emissions (provisional) during the reference period (Cabo Delgado)

Piriod	emissions/removals (CO2-ton)		Annual emissions/removals (CO2-ton/yr)		
	Gross emissions	Gross removals	Gross emissions	Gross removals	Net emissions (removals)
2002 - 2003	3,339,379	165,700	1,113,126	55,233	1,057,893
2003 - 2004			1,113,126	55,233	1,057,893
2004 - 2005			1,113,126	55,233	1,057,893
2005 - 2006	2,267,074	118,937	755,691	39,646	716,046
2006 - 2007			755,691	39,646	716,046
2007 - 2008			755,691	39,646	716,046
2008 - 2009	1,872,568	0	936,284	0	936,284
2009 - 2010			936,284	0	936,284
2010 - 2011	5,163,634	0	1,721,211	0	1,721,211
2011 - 2012			1,721,211	0	1,721,211
2012 - 2013			1,721,211	0	1,721,211
Annual Average			1,149,332	25,876	1,123,456
FRL from 2018 forward by average method					1,123,456

Gaza Province:

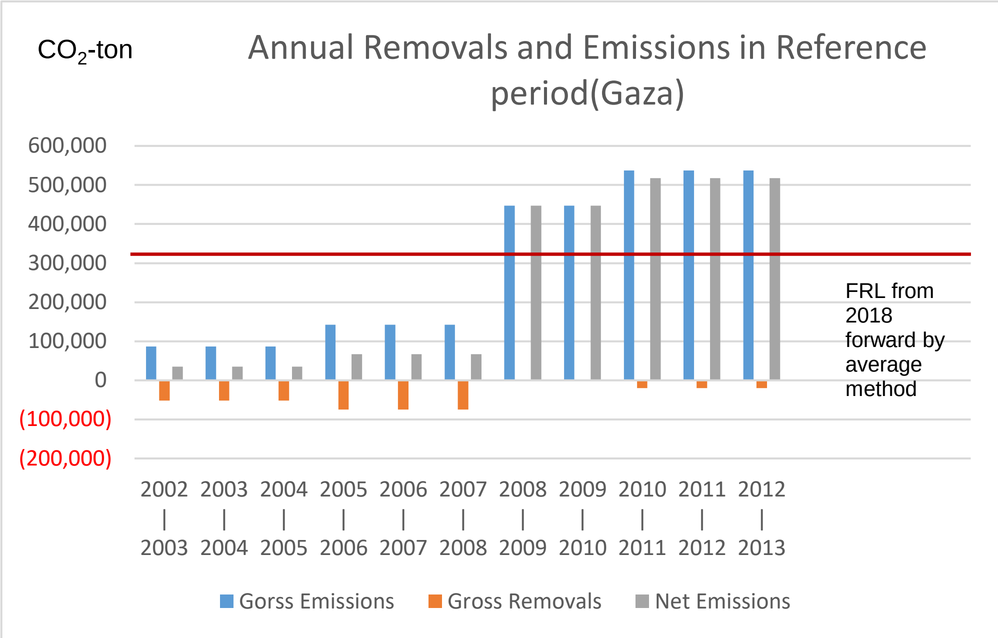


Figure 6.5 Emissions/removals of carbon stocks during the reference period (Gaza)

Table 6.4 Calculation of the mean annual net emissions (provisional) during the reference period (Gaza)

Piriod	emissions/removals (CO2-ton)		Annual emissions/removals (CO2-ton/yr)		
	Gross emissions	Gross removals	Gross emissions	Gross removals	Net emissions (removals)
2002 - 2003	259,199	154,344	86,400	51,448	34,952
2003 - 2004			86,400	51,448	34,952
2004 - 2005			86,400	51,448	34,952
2005 - 2006	425,908	224,620	141,969	74,873	67,096
2006 - 2007			141,969	74,873	67,096
2007 - 2008			141,969	74,873	67,096
2008 - 2009	893,752	227	446,876	113	446,763
2009 - 2010			446,876	113	446,763
2010 - 2011	1,610,894	59,374	536,965	19,791	517,174
2011 - 2012			536,965	19,791	517,174
2012 - 2013			536,965	19,791	517,174
Annual Average			289,978	39,869	250,108
FRL from 2018 forward by average method					250,108

6.4 Capacity building Program for FRELs/FRLs

For FRELs/FRLs, capacity building was promoted as follows. (1) Holding the seminar on FRELs/FRLs. The seminar provided lectures on what the FRELs/FRLs are, procedure of developing FRELs/FRLs and points to be considered for developing FRELs/FRLs on the basis of the COP decisions. Moreover, explaining the outlines of FRELs/FRLs that have been submitted to UNFCCC and methods of developing FRELs/FRLs applied by other countries, the information was provided as reference to analyzing the methods of developing FRELs/FRLs, which are to be applied in Mozambique. (2) Holding technical working group (TWG) meetings for the OJT purpose. Discussing various subjects in TWG meetings supported the counterpart personnel understand REDD+ and its relevant issues.

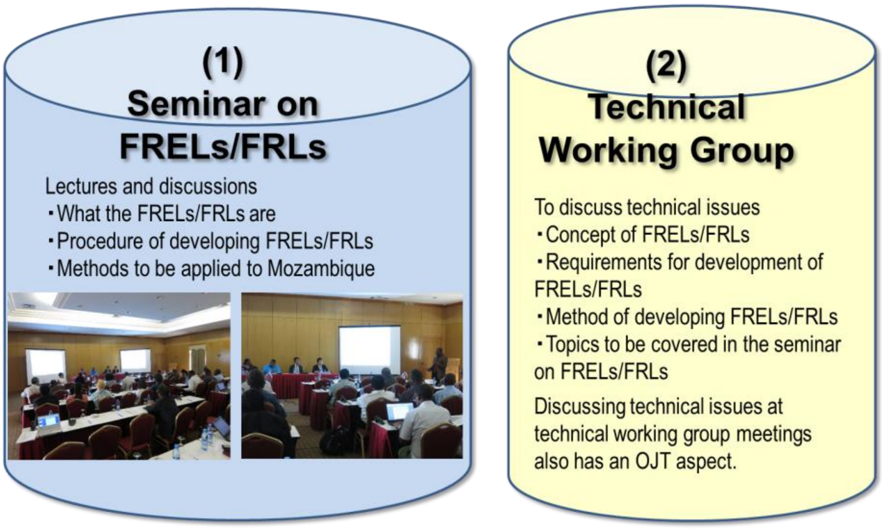


Figure 6.6 Capacity Building Program for FREL/FRL

7 The Preparation of Guidelines and Manuals

The Project prepared nine guidelines and manuals, which shown in Figure 7.1 below. The outline of each guidelines and manuals is as follows.

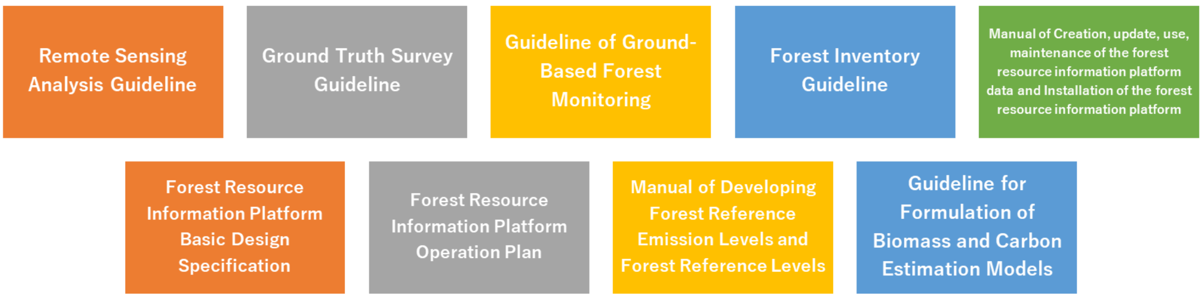


Figure 7.1 Preparation of Guidelines and Manuals by the Project

(1) Remote Sensing Analysis Guideline

Development of forest cover/land use map: work procedures regarding acquisition and examination of existing data, confirmation of satellite imagery specifications, processing of satellite imagery, examination of classification items, imagery interpretation methods, and accuracy assessment for classification results, etc.

Development of reference year maps: work procedures regarding conversion from digital numbers to reflectance values, index data preparation, calculation of differences, principal component analysis, segmentation, automatic detection of change areas, classification using GIS, superposition of change area maps and a base map, preparation of change matrix, etc.

(2) Ground Truth Survey Guideline

Preparation and Implementation of GT surveys: display and interpretation of optical satellite imagery and selection of survey points, survey items and method, important points on field survey, etc.

Organization of GT survey results: Organization methods of GT data, import of GT data into GIS, and preparation of GT point forms using optical satellite imagery and GT survey results, etc.

(3) Guideline of Ground-Based Forest Monitoring

The guideline provides guidance on how to develop Ground-Based Forest Monitoring regularly to grasp a situation of forest. Method of Forest Monitoring as : 1) outline of the guideline such as objectives, intended audience, and how to use the guideline, 2) the flow of the implementation of forest monitoring, 3) Procedure of each topic mentioned in the flow.

(4) Forest inventory guideline

Design and method of forest inventory: Calculation method of necessary number of clusters, shape of cluster, cluster setting method, shape and area of plot, survey item for inventory, permanent plot setting method, etc.

(5) Manual of Creation, update, use, maintenance of the forest resource information platform data and Installation of the forest resource information platform

Creation, update, use, maintenance of the forest resource information platform data: Objectives of the forest resource information platform, access to the platform, creating/editing/correcting articles and menu, setting users, backup and updating database, adding/correcting maps, etc.
Installation of the forest resource information platform: Installing and setting the platform mail program and map program

(6) Forest Resource Information Platform basic design specification

Objectives and function outline of the forest resource information platform, platform functions, software and device configuration, notes on development, functional requirement, screen transition, screen configuration, summarization processing and calculating of forest inventory survey results summary program

(7) Forest Resource Information Platform operation plan

Platform Objectives, users and authority, operation conditions, operation items, operation system, operation plan(handling various inquiries from users on platform, incident and problem management, status and changes of the hardware and software, monitoring and checking of operation, information security management , etc.)

(8) Manual of Developing Forest Reference Emission Levels and Forest Reference Levels

Points to consider for making decisions on preconditions of developing FRELs/FRLs: Scale; definition of forests; REDD+ activities; carbon pools; reference period, etc.
Setting FRELs/FRLs: Methods of analyzing the historical data and projecting future emissions; adjustment of FRELs/FRLs by national circumstances, etc.

(9) Guideline for Formulation of Biomass and Carbon Estimation Models

Development of the biomass and carbon estimation model: Explaining the process of developing a model of estimating biomass and carbon stocks; points to consider for developing a model of estimating biomass and carbon stocks, etc.
Proposed model of estimating biomass and carbon stocks in Mozambique: Explaining the biomass and carbon stock estimation model proposed for Mozambique, etc.

8 Recommendations on How to Utilize the Outputs of the Project

How to utilize the outputs created in the Project were examined towards sustainable forest management and REDD + implementation, then they were summarized below as the recommendations.

First of all, the following Figure 8.1 shows how to utilize the outputs for sustainable forest management and implementation of REDD + according to the main four outputs of the Project, which are 1) forest resource information platform, 2) forest cover/land use maps and the change maps in the two provinces, 3) data of forest inventory survey in the two provinces, 4) Extracted deforestation area using radar images. The ones described in the figure are only particular important methods of utilization, which can be regarded as an outline of utilization of outputs.

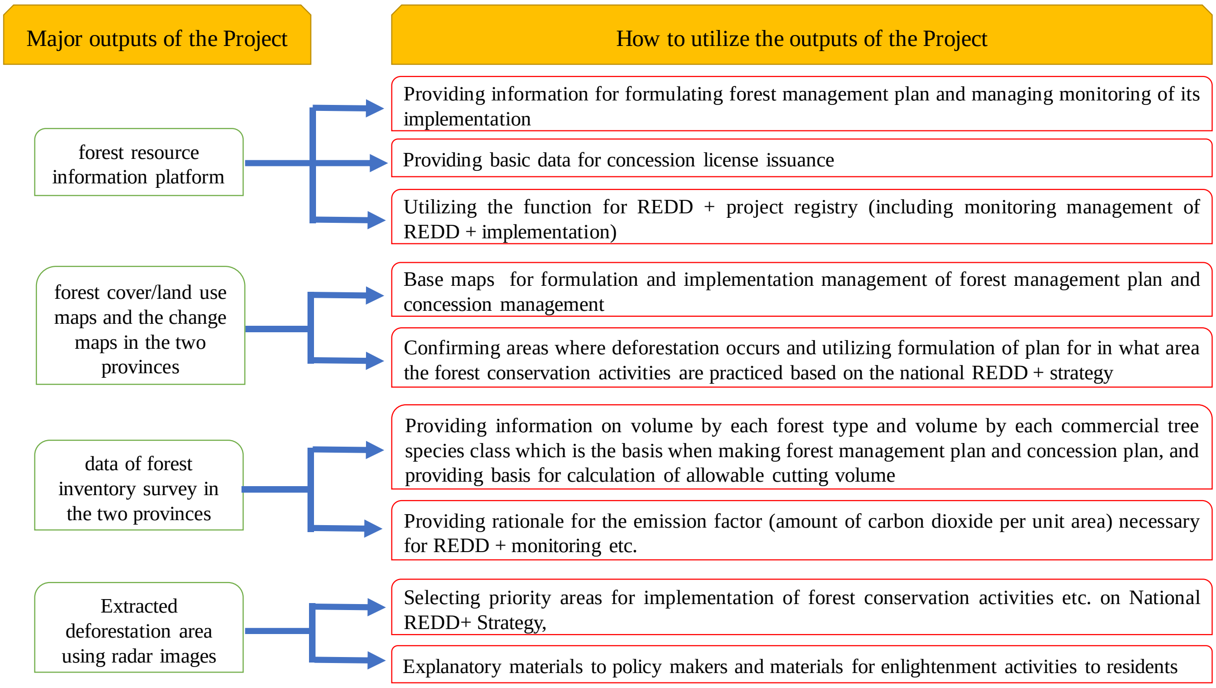


Figure 8.1 Outline of utilization method for each major output of project

Next, for each policy task for sustainable forest management and implementation of REDD +, more detailed discussion of how each output of the project can be utilized and what will be issues in the future are mentioned in the Figure 8.2 to 8.3 below. The sustainable forest management as policy tasks has been further divided into 1) formulation and implementation of forest management plan including concession plan for logging, 2) controlling illegal logging, and the implementation of REDD+ has been further divided into 1) actual implementation of REDD+ activities 2) update of FRL, 3) formulation and implementation of NFMS. Then, how to utilize the outputs by each sub-policy task divided as aforesaid were examined and agreed at the final JCC.

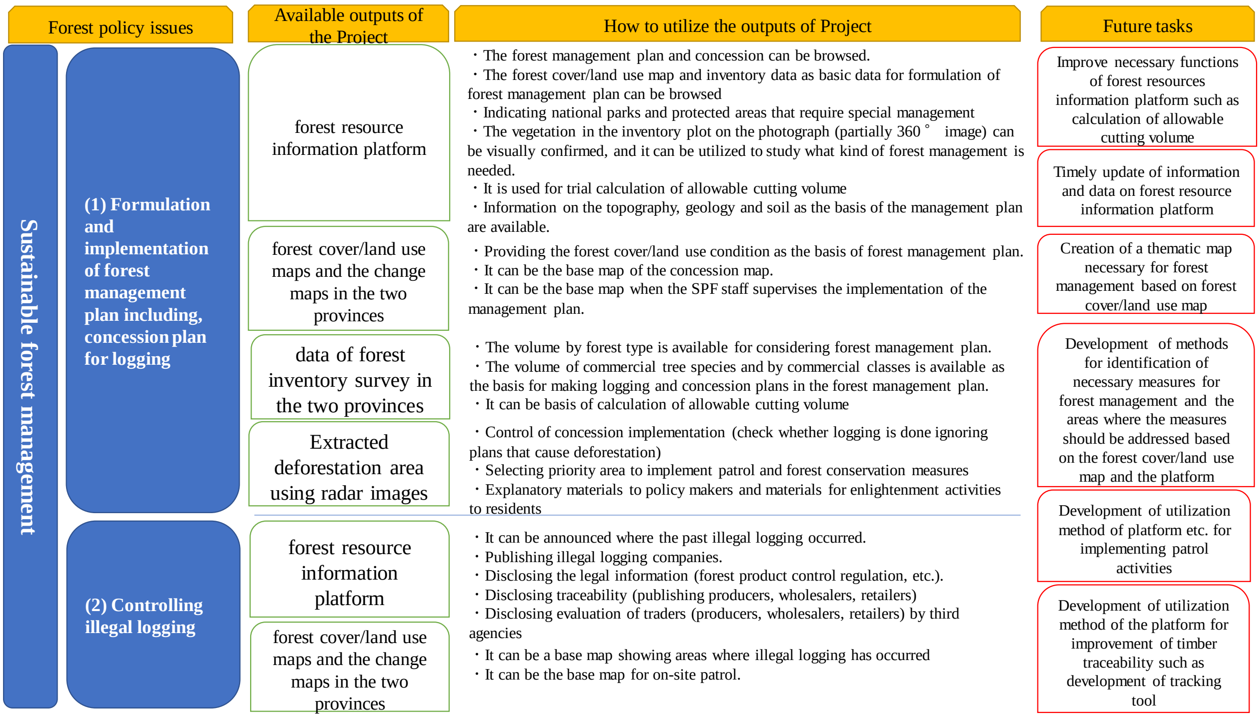


Figure 8.2 How to Utilize Project Outputs for Sustainable Forest Management (Detailed Methods on Policy Issue Basis)

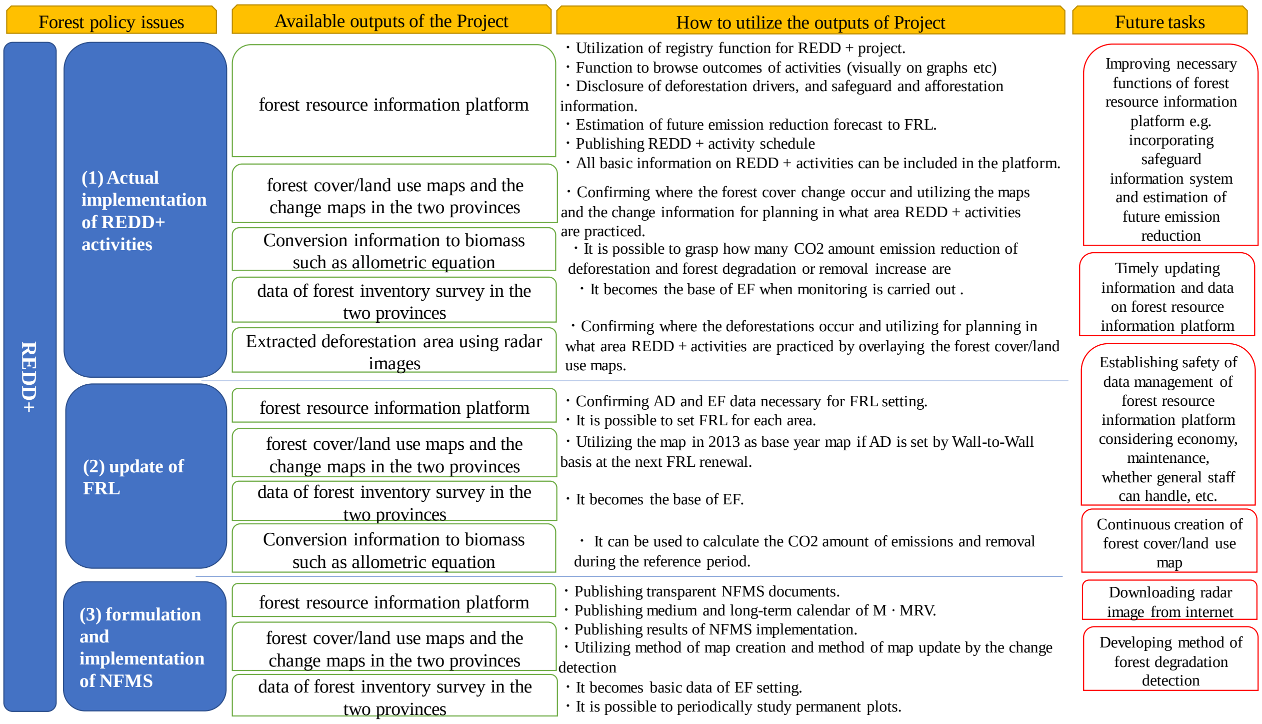


Figure 8.3How to Utilize Project Outputs for REDD+ (Detailed Methods on Policy Issue Basis)