Forest Carbon Partnership Facility (FCPF) Carbon Fund ER Monitoring Report (ER-MR)	
ER Program Name and Country :	Emission Reduction Program in Atiala Atsinanana (ERP-AA), Republic of Madagascar
Reporting Period covered in this report:	From 22/03/2020 to 31/12/2020
Number of FCPF ERs:	1,764,499
Quantity of ERs allocated to the Uncertainty Buffer:	213,103
Quantity of ERs to be allocated to the Reversal Buffer:	563,660
Quantity of ERs to be allocated to the Pooled Reversal buffer:	122,534
Date of Submission:	17/06/22
Version	5.1

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

LIST OF FIGURES

ACRONYMS

AD	:	Activity Data
AGB	:	Above-ground biomass
BGB	:	Below-ground biomass
BIF	:	Birao Ifoton'ny Fananan-tany
BNCCREDD+	:	National Office of Climate Change and REDD+
BSP	:	Benefit-Sharing Plan
CAS	:	Special Allocation Account
CAZ	:	Ankeniheny-Zahamena Corridor
CDPs	:	Communal Development Plans
CEF	:	Forest Cantonment
CI	:	Conservation International
CIME	:	Committee for the Environment
CLP	:	Local Commitee of the Park
COBA	:	Community-Based
COMATSA	:	Corridor Marojejy Anjanaharibe Sud Tsaratanana
COSAP	:	Orientation and Monitoring Commitee of the Protected Area
CRBA	:	Community Rights-Based Approach
CTD	:	Decentralised Local Authorities
DD	:	Deforestation and Forest Degradation
DGGE	:	Directorate General of Environmental Governance
DNA		Designated National Authority
DRAE	:	Regional Directorate of the Agriculture and Livestock
DREDD	:	Regional Directorate of the Environment and Sustainable Development
DRGPF	:	Directorate of the Reforestation and the Forest Landscape Management
DRMCF	:	Decree on the regulation of access to the forest carbon market
EF	:	Emission Factors
EO	:	Earth Observation
ER	:	Emission Reduction
ERP	:	Emission Reduction Program
ERPAA	:	Emission Reduction Program "Atiala Atsinanana"
ERPD	:	Emission Reduction Program Document
ESMF	:	Environmental and Social Management Framework
FCPF	:	Forest Carbon Partnership Facility
FF	:	Functional Framework
FMS	:	Forest Monitoring System
FPIC	:	Free, Prior and Informed Consent
FRA	:	Forest Resources Assesssment
FREL	:	Forests Reference Emission Levels
GFOI	:	Global Forest Observations Initiative
GFW	:	Global Forest Watch
GHG	:	GreenHouse Gas
IPCC	:	Intergovernmental Panel on Climate Change
LOFM	:	Forest Observation Laboratory in Madagascar

LULUCF	:	Land Use, Land Use Change and Forestry
MAEP	:	Ministry of the Agriculture and Livestock
MBG	:	Missouri Botanical Garden
MECIE	:	Compatibility of Investments with the Environment
MEDD	:	Ministry of the Environment and Sustainable Development
MEF	:	Ministry of Economy and Finances
MGD		Methods and Guidance Documentation
MGP	:	Complaint Management Mechanism
MMR		Monitoring, Measuring and Reporting
MNP	:	Madagascar National Parks
MRV	:	Measurement, Reporting, and Verification
NAP	:	New Protected Area
NFMS	:	National Forest Monitoring System
NGO	:	Non-Governmental Organization
ONE	:	National Office for the Environment
Ops	:	Operational Policies
OSC	:	Civil Society Organization
PA	:	Protected Area
PADAP	:	Sustainable Agriculture Project through a Landscape Approach
PAP	:	People Affected by the Project
PERR-FH	:	Eco-Regional REDD Program in Humid Forests
PLOF	:	Local Plan for Land Occupation
PLUT	:	Utilization Plan
QA/QC	:	Quality assurance/quality control
REDD+	:	Reducing Emissions from Deforestation and Forest Degradation
RL	:	Reference Levels
RRC	:	Regional REDD+ Cordination
SESA	:	Strategic Environmental and Social Assessment
SIIP	:	REDD + Initiatives and Programs Information System
SIS	:	Safeguards Information System
SOPs	:	Standard Operating Procedures
TEC	:	Technical Evaluation Committee
TGRN	:	Management Transfer of natural resources
UNFCCC		United Nations Framework Convention on Climate Change
UOT	:	Land Use and Occupation
VOI	:	Vondron'olona Ifotony
VSLAs	:	Village Savings and Loan Associations
WCS	:	Wildlife Conservation Society
WWF	:	World Wildlife Fund

1. Implementation and operation of the ER program during the reporting period

1.1. Implementation status of the ER Program and changes compared to the Emission Reduction Program Document (ER-PD)

In terms of priority activities and intervention areas, there is no change to the Emission Reduction Program. The "Atiala Atsinanana" ER Program intends to address the drivers of deforestation developed in the ER-PD through two main means which are (1) to strengthen interventions within the 15 existing initiatives and (2) promote targeted interventions for the Program areas that are not covered by REDD+ initiatives.

Table 1 : Actions and interventions under the ER Program

Key dates	Activities
2018	- Submission of the Emission Reductions Program Document (ER-PD) - Adoption of the national REDD+ strategy by the decree N°2018-500 on may, 30th 2018 - Elaboration of the Alaotra Mangoro, Atsinanana, Analanjirofo, Sofia, SAVA, Boeny, Menabe et Atsimo Andrefana regional REDD+ strategy - Establishment of the governance and institutional framework of REDD+ mechanism (national REDD+ Plateform, Regional REDD+ Plateforms)
2019	- Implementation of the Information System on Program Initiatives (SIIP) - Development of REDD+ implementation frameworks on environmental and social safeguards
2020	- Development and implementation of the REDD+ transactional register - Establishment of the Complaints Management Mechanism - Inventories of the Eastern Humid Forests - Mapping of the "Atiala Atsinanana" Emissions Reduction Program area, according to the Land Use and Occupation classification system (UOT) and definition of forests over the course of the year, by the Madagascar Forest Observation Laboratory (LOFM), BN-CCCREDD+ geomatics laboratory - Analysis of national deforestation: mapping of changes for the periods 2000-2005-2010-2015-2019 over the course of the year

Activities implemented in existing initiatives:

The Atiala Atsinanana Program currently has 15 protected area initiatives covering 60% of the Program, and implemented by 06 promoters. Knowing that deforestation within the conservation cores is relatively stabilized, each initiative of the Program is delimited with a 2.5km buffer zone around the PA in which the main challenge will be to reduce the deforestation rate.

The promoters are working to continue their responsibilities as delegated PA managers and are investing in conservation and restoration.

Typical activities implemented within PAs include:

- Monitoring and surveillance: ground and aerial patrols in collaboration with communities, the Forestry Administration and law enforcement agencies
- Reinforcement or maintenance of conservation infrastructure: marking of park boundaries, setting up of firefighting committees/brigades, brigades' equipment
- Operationalization of the grievances collection and treatment system
- Restoration/Reforestation
- Ecological monitoring
- Implementation of community-based participatory management: contract for the transfer of the green belt management to communities (VOI), capacity building and support to COBA/VOI
- Strengthening local governance: support and capacity building for the PA Steering Committee (COS/COSAP)
- Implementation of Information, Awareness and Education Programs

- Development of community conservation enterprises and income-generating activities: alternative industries, agroforestry, conservation agriculture, others

As the Program has not yet received any REDD+ payments or initial advance for this first period, its interventions in 2020 are entirely financed by the initial investments made by the promoters.

Intervention strategy in areas outside the initiatives:
Currently, 40% of the Program area is not concerned by any REDD+ intervention. This area outside the initiatives represents 16% of the Program's forests with twelve forest blocks. The risk for the Program is to see deforestation relocate outside the initiatives, in these unmanaged areas. In addition, since the deforestation rate is already three times higher than in existing initiatives, a specific strategy is being developed to implement targeted activities and promote other potential initiatives.
The strategy will start with the implementation of field agents for on-site monitoring, awareness raising, context analysis and the development of targeted activities to address the causes of deforestation. The areas outside the initiatives are remote and difficult to access; interventions will be carried out progressively over five years, prioritizing three pilot areas at the beginning of the implementation. This Strategy outside the initiative has been developed and discussed with the Forestry Administration at the regional level during 2020 and should be implemented as soon as the initial advance requested for the Program is available. It will be implemented by the Regional REDD+ Coordinators.

Strategy to minimize/master displacement:
The process of formulating and planning REDD+ activities to be implemented ensures the involvement of all stakeholders - including communities - in order to effectively respond to deforestation and community needs. This principle of matching activities to the context should greatly contribute to reducing the risks of leakage.
Masoala - where this risk was most likely - was integrated into the ER Program (at the request of the FCPF). The forests affected by possible leakage constitute part of the ER Program's protected areas, but outside its administrative boundaries (case of Marotandrano, Mahimborondo and COMATSA). The other forest blocks around are under the responsibility of delegated managers (cases of Bemanevika, Tsaratanàna and Anjozorobe Angovo). These forests are in all cases managed by NGOs in co-management with the communities, making the risks of displacement negligible.
However, if cases of significant leakage related to the Program were to occur, funding could be allocated to respond to related emergencies, depending on the decisions adopted by the REDD+ Governance mechanism.

Table 2 : A detailed update on the strategy to mitigate and minimize potential Displacement.

Driver & Agent	Significance of the driver	Risk of displacement and related activities of the program	Significance of the risk	Mitigation measures
Displacement of deforestation due to Agricultural Expansion				
Annual crops and shifting cultivation / Small farmers and local populations for subsistence agriculture - Emigrant population	High: Tavy system is undoubtedly the main driver of deforestation everywhere on the ERP area, and is used mainly for annual crops	Activity shifting: Displacement of shifting cultivation would require the local population to re-locate their agricultural activities outside the program, but this phenomenon is quite unlikely. Some immigrant populations may decide to relocate within the ER-P in order to access natural resources, and practice shifting agriculture. The improvement of the landscape approach, the reforestation and rehabilitation of degraded and the enforcement of the forest surveillance ant text could force local population to relocate to other areas within the ERP or outside the ERP, but more likely to areas in close proximity within the same watershed or in an adjacent watershed. In view of this and considering the ER program low perimeter/area ratio (and that a large fraction of the perimeter leads to non-forested coastal areas or the dry forest ecoregion), any emissions due to displacement of shifting cultivation and annual crops wouldn't be high, though not negligible.	Medium	The ER-P is designed in a way that all activities implemented will be discussed and planned at commune and landscape scale with the participation of all stakeholders. Only largescale activities could incur a risk of displacement. The ER-P will set up procedures to ensure that design phase consultations of concerned communes will be undertaken and a displacement analysis and mitigation strategy will be developed. In addition, the ER Program incorporates a set of activities aimed at increasing agricultural productivity, diversifying incomes from natural resources and strengthening agricultural value chains with the objective of increasing revenue of agricultural activities (i.e. without increasing production areas) These activities will increase efficiency in the use of existing agricultural land, avoiding the need to migrate due to mitigation activities within the forestry sector.
		Market Effect: most of the agriculture within the ER program area is small scale and primarily subsistence driven. Some produce may be sold but this is primarily to serve local markets as the accessibility to large cities such as Antananarivo is limited by lack of accessible transport infrastructure. Hence no market leakage is likely to occur.		
Permanent crops / Small farmers- Emigrant population	Medium because initially permanent crops are responsible for	Activity shifting: most permanent crops in the ER-P can be produced through agroforestry systems and thus it is very unlikely that some activities of the program could encourage or force local farmers to relocate their	Medium	The displacement risk related to emigration will be monitored during each project design phase (and thus included in the Regional REDD+ Activity Plan)

	deforestation when traditionally implemented but they can also ensure carbon stock enhancement when implemented on fallow land or post tavy secondary forest	production, even more when there is activity which aims to improve agroforestry systems and ensure their sustainability. However, activity linked at improving forest management and reinforcing controls, might to some extent, force local populations without legal land specifically dedicated to permanent crops, to implement their production sites on existing forest lands, thus increasing deforestation - or affecting natural forests by implementing agroforestry systems within intact forest.		and a specific strategy will be designed to anticipate potential negative impacts.
		Market Effect: The program will improve permanent crop production first by improving traditional practices to ensure sustainability, and also by increasing agroforestry areas on fallow lands (and ensuring carbon stock enhancement) when they have a high risk of being burnt through tavy. No market leakage risks can be thus identified in the program because the ER-P aims at improving productivity by encouraging sustainability.		
Fire due to pastoralism and small farmers with beef cattle	Medium	Activity shifting: If improved forest management or new reforestation could constrain the access to land, thus causing activity shifting, it is considered as highly unlikely that local farmers would relocate outside the ER program area because (i) mobility of farmers with beef cattle is very limited, and (ii) REDD+ activity aims to improve cattle breeding practices. No risk identified.	No risks	
		Market Effect: ER-P activities dedicated to cattle breeding and fire management practices will not affect the overall level of productivity, and thus risk of market leakage is negligible.	No risks	
Displacement of deforestation due to wood harvesting				
Construction, softwood and service timber harvesting / Artisanal loggers without authorization	Low, because illegal and artisanal logging is only focused on a limited number of species	Activity shifting: Artisanal logging is not linked to land property; loggers may move to other regions when affected by the program activities aimed at reducing artisanal and illegal logging. Thus, a risk of displacement of artisanal and illegal logging in some areas within the ER-P exists where you can find equivalent high-value wood species (rosewood, palisander).	Medium	The ER Program will not try to reduce artisanal logging but will only ensure that logging is realized legally. Specifically, the ER Program pursues the following strategy: - a REDD+ Activity will improve forest management by developing local landscape plans, in which some

from forest administration		However, due to geographical and topographic constraints but also to a further distance from the coast (where all illegal timber is exported), it seems minimally feasible for artisanal loggers to move in the humid forest located on the west side of the ER-P (Bealanana) for wood exploitation. Market Effect: The ER-P should reduce its timber supply through a limitation of illegal and artisanal logging. Thus, the supply gap may be closed by other agents in other areas of the humid forest ecoregion.		areas will be dedicated to logging and ensure sustainable artisanal logging operations. - a REDD+ Activity will mitigate the risk of displacement in the mid-term by the creation of dedicated afforestation activities according to local needs, including for timber supply. - a REDD+ Activity will support the development of partnerships between local communities and artisanal loggers in order to determine the demand in timber wood and then support the creation of sustainable artisanal logging operations for its supply.
Wood fuel / charcoal production due to local population needs	Medium Although the consumed charcoal mainly comes from eucalyptus plantations, in some part of the ER-P area, charcoal has a more important local impact, in particular due to the increase in the demand from certain urban areas (ex. Fénérive Est)	Activity shifting: Charcoal is mainly produced from eucalyptus plantations but also in lower extent from natural forest, mostly as a byproduct of shifting cultivation. The wood which is cut for future agricultural land is also used for charcoal production. The ER-P programs aims at improving carbonization practices of charcoal made from specific plantations in order to improve energy efficiency; activity FD2 will promote plantations dedicated to charcoal supply. However, there is a risk that activities FI1 could drive illegal producers to relocate in other areas. But considering that the urban areas responsible for a high demand in charcoal are coastal, and considering also the topography of the ER-P area, there is no risk that producers would relocate outside of the ER-P to produce charcoal. Market Effect: The ER Program does not aim to reduce the existing charcoal supply but to moderate the production to the current and near-future demand (potentially increase the production through specific plantations) and improved carbonization practices and so improve energy efficiency. By doing so the ER-P should be able to ensure the needs from urban areas within the program, thus reducing the risk of market leakage.	Low- risk	The ER Program will promote alternative, sustainable, energy sources and increased efficiency of fuel wood production through: - Promote improved fuel wood transformation - and use techniques, as well as the dissemination of improved coal stoves in urban centers; and - Develop the use of renewable energy (solar, biogas, etc.) for domestic use. The ER-P will also work on the enabling framework through: - Support the harmonization and development of the legal framework relating to the development of alternatives to fuel wood and sustainable fuel wood supply
Displacement of deforestation due to mining				
Miners	Low	Activity shifting and market effect: Mining activities are geographically dependent on available resources, and the ERP does not aim at stopping mining activities but only	No risks	

		improve their practices and implement compensatory reforestation when necessary. There is no risk of shifting.		

Effectiveness of organizational arrangements and involvement of partner organizations:
Coordination of the Atiala Atsinanana ER Program is ensured by the National Office in charge of REDD+. During 2020, five Regional REDD+ Coordination structures were established by protocol and strengthened in equipment and capacity to allow for the delegation of part of the Program management to the five implementation regions. The National Office in charge of REDD+ is continuing to transfer skills to the regional level in order to supervise and manage REDD+ initiatives.
Regarding the operational management of REDD+ activities, the six initiative promoters ensure the supervision and technical and financial support of intra-initiative activity actors, and monitor and report on the implementation of REDD+ activities. As this accountability is already established vis-à-vis the Forest Administration, there are no major difficulties in operationalizing the institutional arrangements. However, capacity building and dialogue are planned for familiarization with the new implementation tools.
Nevertheless, it is important to emphasize that the planning and validation process through the REDD+ Governance arrangements will only be truly operationalized at the planning stage of the initial advance requested for the Program, which will be the first payment, among other things (probably in the next reporting period).

Program funding:
During the five years of implementation, the program activities will be financed by the initial investments made by the promoters and by the payments made by RE. The investments made by the promoters allow for the financing of all current activities within the PAs but are not sufficient to provide additionality in the activities and in the search for ER performance. Thus, REDD+ payments should allow for this additionality, without replacing existing funding.
An initial advance has been requested for the Program to fund additional activities and efforts within existing initiatives as well as to fund strategy implementation outside of initiatives in the remaining 40% of the Program.

Table 3 : Expected funding plan for the PREAA

Funding	Objectives	Intervenes from :
Initial investments made by the promoter	- Fund/maintain the ongoing operations of the initiative	Annually without ever being substituted by carbon revenues
Initial advance	- Fund additional activities within existing initiatives - Fund interventions in the area outside the initiatives	From the second period
REDD+ payments, including interim advances after notification of ER (following PPB)	- Finance additional activities within existing initiatives - Finance extensions of activities within or outside of initiatives - Finance interventions in the area outside the initiatives - Finance REDD+ governance and implementation mechanisms	Each period

Setting up institutional tools: Decree on the regulation of access to the forest carbon market

The Decree on the regulation of access to the forest carbon market was adopted at the end of 2021; its purpose is to regulate access to the forest carbon market (https://www.environnement.mg/?wpdmpro=decret-relatif-a-la-regulation-de-lacces-au-marche-de-carbone-forestier#)

Baseline Update: Forest Inventory, Historical Deforestation Analysis

Emission factors are updated according to the most recent inventory results: a systematic inventory following a national grid of 4 km x 4 km established by the Forest Observation Laboratory in Madagascar (LOFM) in collaboration with the Directorate General of Environmental Governance (DGGE). The Methodology Division within the BNCCREDD+ ensures the update of the emission factors.

The update of the historical analysis of national deforestation for the 2000 to 2019 period (2000-2005; 2005-2010; 2010-2015 and 2015-2019) according to the definitions of forests applied to REDD+, and the classification system of Land Use and Occupancy (UOT) in Madagascar allowed to know the evolution of the forest cover in the country including the areas of the PREAA Program. In addition, the collection of Activity Data - to have a reference on the level of deforestation and forest degradation and its changes over the reference period and the monitoring period - provided information on the forest cover evolution (determination of the importance of deforestation and forest degradation). The LOFM or Forest Observation Laboratory in Madagascar updates the activity data.

The reference emission level for forests (NERF) of the PREAA Program, which is the reference point for the measurement of emissions related to deforestation, forest degradation and sustainable forest management, was established according to the latest data (new emission factors, new activity data).

Performance Evaluation

The performance assessment is conducted annually in the ERP AA program area, and every two years in non-initiative areas to determine leakage and strategies for managing it. Carbon performance is established by the LOFM and the Methodology, which work in concert to achieve the REDD+ MRV. The MRV or Measurement, Reporting, and Verification is the system for carrying out activities to calculate emission and removal factors, analyze activity data to develop the NERF, and measure performance in terms of emission reductions from deforestation and forest degradation, removals related to conservation of forest carbon stocks, and enhancement of forest carbon stocks.

1.2 Update on major drivers and lessons learned

According to an analysis by the SalvaTerra consortium - Université Catholique de Louvain, led by SalvaTerra; the agents, direct causes and underlying drivers of DD that builds on studies conducted in 2014 by the World Bank-funded Eco-Regional REDD Program in Humid Forests (PERR-FH), including analysis of forest cover change in the 2005 to 2010 and 2010 to 2013 periods across Madagascar:

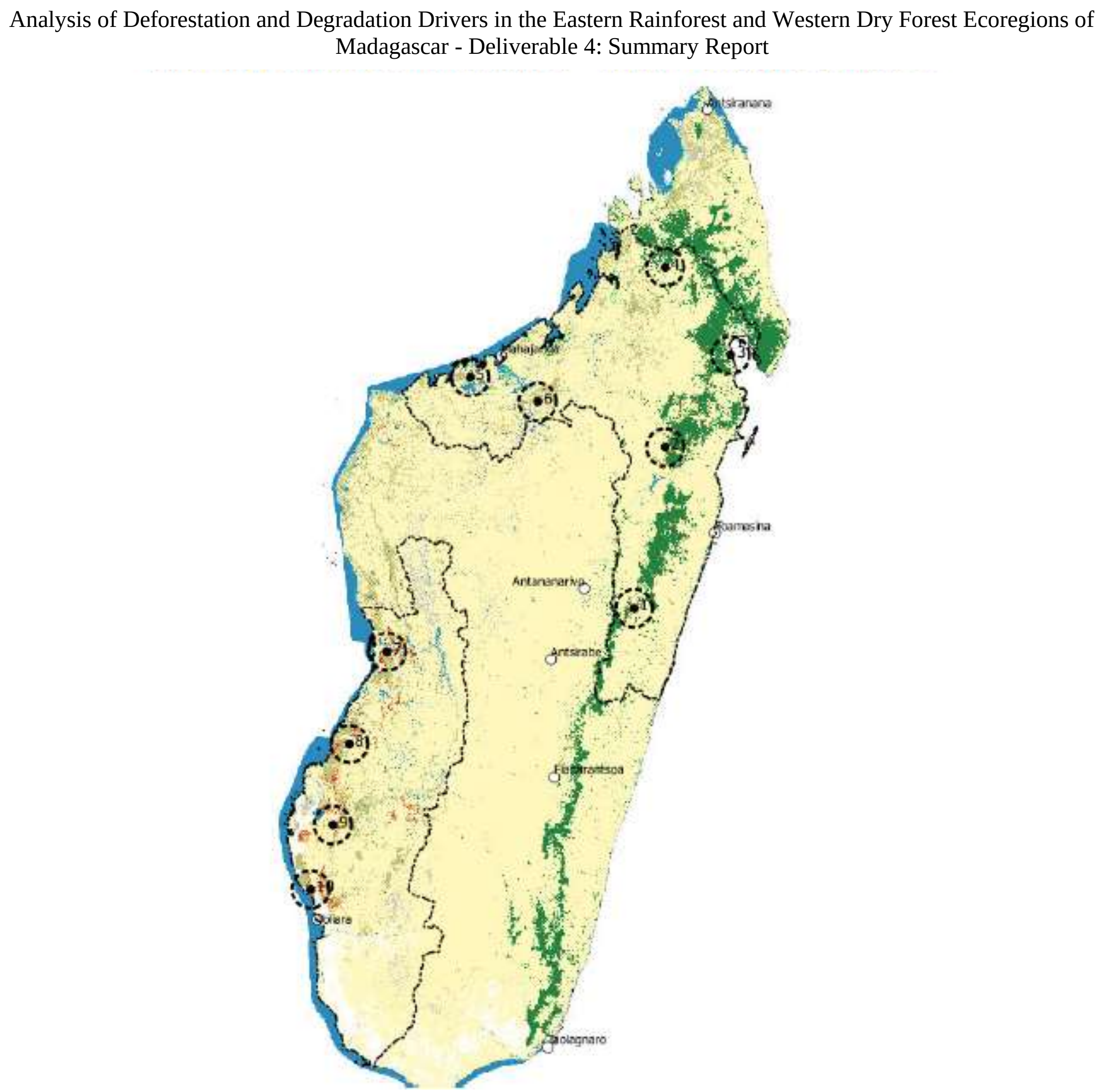
The overall objective was to contribute to the development of the national REDD+ strategy through the development of information on deforestation and forest degradation mechanisms, to prioritize and refine the REDD+ strategy options proposed within the framework of the R-PP of Madagascar. The specific objectives of the analysis were:

- Identify the agents, direct causes and underlying drivers of DD in the study area;
- Assess the impacts of the different causes and underlying factors on DD and thus on related emissions through detailed projections of deforestation trends over the next 10 years in the study area;
- Spatially and qualitatively analyze the agents, direct causes and underlying factors of DD in the study area in order to identify strategic directions for combating DD;
- Evaluate the impacts of the identified REDD+ strategic orientations to prioritize them;
- Analyze agricultural practices and the dynamics of expansion of agricultural land and other land uses.

The field surveys targeted deforestation hotspots in the Analanjirofo, Alaotra Mangoro, Atsinanana and Sofia zones, which were regions concerned by the ER-P area.
The sampling - which covered 10 areas - was not intended to cover the full diversity of deforestation and degradation processes in the country, but to illustrate the diversity of drivers and pressure processes on forests, by targeting areas considered a priori to be representative of deforestation and degradation at the country level.
Sampling was based on the state of knowledge in the literature on this topic, available mapping data (historical deforestation of the PERR-FH), the location of conservation areas (PA, TGRN) and production areas (KoloAla), the location of the ecoregions of the PERR-FH, and the distances between areas.

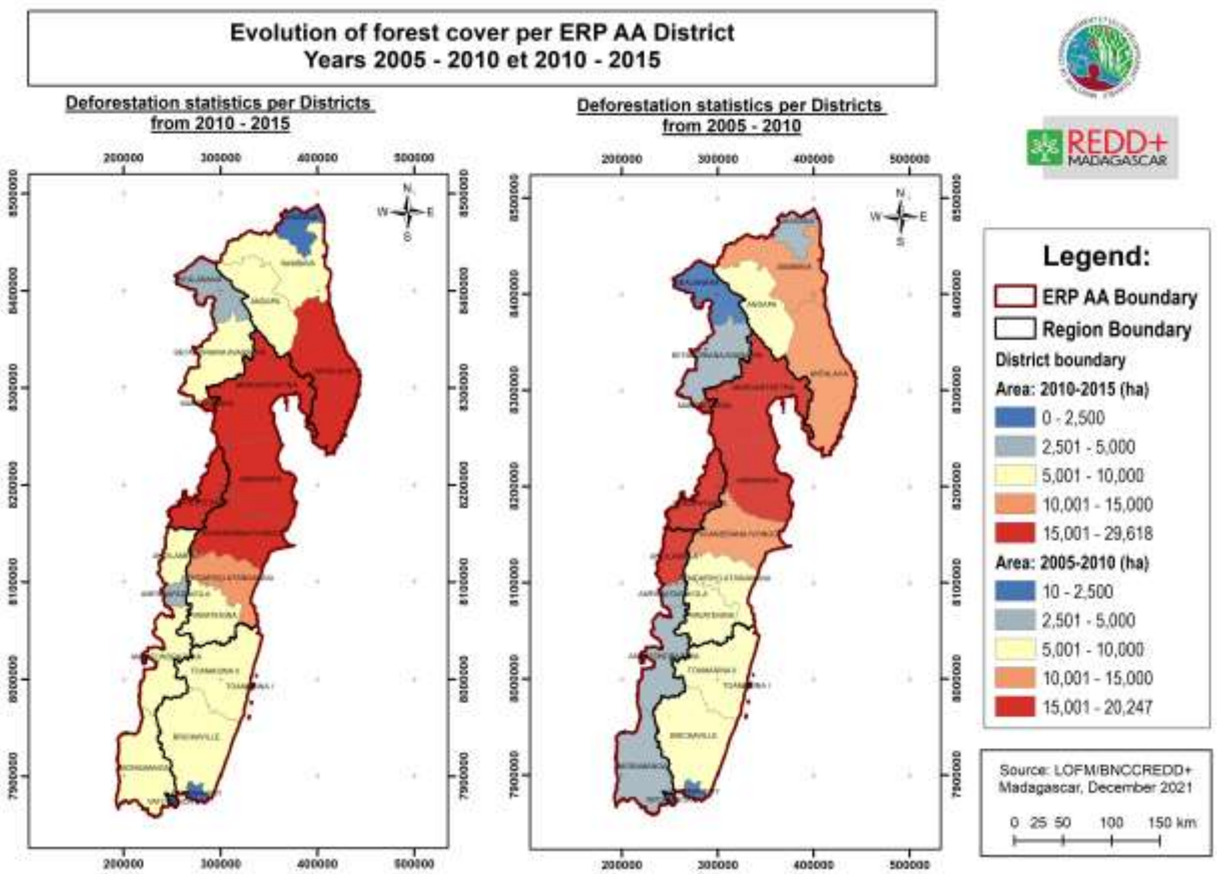
At the national level, the ten hotspots were identified based on deforestation, their specificities and their spatial distribution according to the 2005-2010 and 2010-2013 PERR-FH map:

1. Anosibe An'ala;
2. Andilamena (Program area) ;
3. Rantabe (Program area) ;
4. Bealanana (Program area) ;
5. Mitsinjo;
6. Ankarafantsika ;
7. Belo sur Tsiribihina ;
8. Belo-sur-mer ;
9. Est de Morombe ;
10. Ranobe



Map 1: Location of the 10 deforestation hotspots targeted during the field surveys

This result was updated with the national deforestation map produced in 2020-2021 for the 2000-2005; 2005-2010; 2010-2015 and 2015-2019 periods with the following map:



Map 2: Deforestation Statistics by ERP-AA District

The ERP AA districts are ranked in order of importance of deforestation.

During the LOFM field surveys that occurred on the year 2021, four regions of the ERPAA were concerned: Alaotra Mangoro, Atsinanana, SAVA and Analanjirofo in order to identify the drivers of deforestation and degradation. The Sofia region was not listed as itinerary for this first monitoring. The drivers of deforestation and degradation remain the same as that were described in the ERPD and Salva Terra findings.

Regarding the causes of deforestation and forest degradation, the results by ecoregion by engine type are presented in the following table according to Salva Terra and the results of the field surveys conducted by LOFM

Table 4: Causes of deforestation and forest degradation

Engine Type	***Results from the DD engine study (March 2017)***	***LOFM study results (surveys, mapping) (2021)***	***Regions concerned (LOFM study)***
Transportation infrastructure and accessibility	In the eastern humid forests, it appears that Districts are more deforested when their forests are not easily accessible. The general lack of access to forests can	This statement remains valid for the Program area, such as the forests of the Ankeniheny Zahamena Corridor in	Alaotra Mangoro, Analanjirofo

	concentrate pressures (e.g., harvesting, slash-and-burn, etc.) on the few areas of more accessible forest.	the Alaotra Mangoro Region, Ambatondrazaka District in part, which are difficult to access in general (impassable roads, especially in rainy periods). In this area, according to the deforestation maps produced, deforestation remains significant and well localized. For Analanjirofo also, in the Makira forests, deforestation remains as important, the forest is not accessible by road.	
Mining	The impact on deforestation of artisanal mining is low. The minerals encountered in humid forests share common characteristics: extraction (or collection in the case of quartz and crystal) on a small scale, in an artisanal manner (using angady, possibly with crowbars, as well as prospecting pans in the specific case of gold), with marginal impact on forests. These mines could be an important driver of forest degradation in the eastern humid forests and the Ankeniheny-Zahamena Corridor (CAZ) in particular - in a punctual manner in space and time - due primarily to wood harvesting for the miners and their families' needs. However, the suspected extent of the sapphire and ruby deposit in the CAZ may result in greater impacts on this forest in the future.	Spatial analyses for 2000 to 2019 showed significant deforestation in the CAZ forests, hypothetically due to this gem mining.	Alaotra Mangoro
Permanent crops	In the eastern humid forests, this crop could be responsible for deforestation. The largest areas are located mainly in an 80km wide coastal strip in Vatovavy Fitovinany (Ifanadiana, Nosy-Varika, Mananjary and Ikongo Districts), Atsinanana (Brickaville, Mahanoro, Marolambo and Toamasina II	As results for the study on 2021, permanent crops are responsible for forest degradation: culture of rice, clove, … It is also a way to land grabbing. These cases were confirmed, as an example is the District of Maroantsetra.	Analanjirofo, Atsinanana

	Districts), Analanjirofo (Fénérive Est and Fénérive Est and Vavatenina) and in the Mandritsara District of the Sofia Region. It is possible that the process of establishing lucrative perennial crops will follow two phases: a first one - negative in terms of REDD+ - where plots are few in an area and where farmers are encouraged to deforest in order to create plots specifically dedicated to cash crops, having to keep their initial ones for their food production; and a second one - positive in terms of REDD+ - where old clearings (savoka) are numerous and conducive to the installation of these agroforestry crops, resulting in a stabilization or even a halt of deforestation.		
Annual crops	The bibliography unanimously identifies slash-and-burn agriculture as the primary driver of deforestation. The main indicator is the apparent maintenance of yields, which can only be explained by this practice. In addition, households are in an extensification logic, agricultural innovation is very low (traditional seeds, manual plowing, basic equipment, almost non-existent agricultural supervision, etc.), the limited availability of plains and lowlands encourages rainfed cultivation, clearing of land - which is not widely accepted - is widespread, and the use of fertilizers is rare. In the eastern humid forests, tavy generally involves the cultivation of rainfed rice (for self-consumption) followed by maize, cassava, sweet potatoes, and then fallow. The rotation duration is more than 5 years. For various reasons, slash-and-burn is the most competitive agricultural system in the in the ERP AA region, and is the most commonly practiced. However, farmers across Madagascar are reluctant to say they	During the studies (monitoring conducted by LOFM and Methodology), it was found that this practice is a main cause of deforestation noted in the Alaotra Mangoro, Analanjirofo, Atsinanana Regions.	Analanjirofo, Alaotra Mangoro, Atsinanana, SAVA

	practice tavy, though evidence indicates that slash-and-burn agriculture is widespread. The main indicator of tavy is the stagnation of crop yields, which can only be explained by this practice (a non-tavy, more modern or intensified system would produce measurably higher yields). Increasing household needs often leads to expansion of tavy plots and new deforestation, rather than to agricultural innovation, due to limited access to extension services and technology to support innovative approaches. Agricultural innovation is very low in this area, which relies on traditional seeds, manual plowing, basic equipment, almost nonexistent agricultural supervision, rare use of fertilizers. Lack of available land in plains and lowlands encourages rain-fed cultivation and clearing. Practiced more and more frequently in time and space, it makes deforestation permanent: the regular use of fire makes forest regeneration impossible.		
Livestock	Spatial and survey-based analyses show that livestock production is not an important direct driver of deforestation or forest degradation, as grazing in the forest remains exceptional.	According to the information collected, livestock farming was not indeed presented as a factor of deforestation.	Analanjirofo, Alaotra Mangoro, Atsinanana, SAVA
Commercial timber exploitation	The bibliography emphasizes that there is generally overexploitation (no logging inventory, corruption of agents, etc.), large losses (40% to 80% of the wood harvested) and perverse induced effects: Land grabbing under the cover of a logging permit, infiltration of villagers into the massifs through access roads, etc. In humid forests, the harvesting of commercial timber seems to have little impact, as the market for these products is not very developed. No evidence of large-scale illegal logging has been collected. Precious woods (rosewood, ebony, etc.) have experienced a boom with	During the monitoring carried out by LOFM and Methodology, it was noted that timber trafficking, commercial logging - whether legal or not - are among the important direct causes of deforestation on both a small and large scale. This has been noted, for example, in the Alaotra Mangoro Regions, near the Analamazaotra, Mantadia and Zahamena Initiative areas. The commercialization of wood plays a more or	Alaotra Mangoro

	the 2009 crisis (fivefold increase in the volume of rosewood, mainly exported to China) and are exploited in the Northeast Regions. This situation could explain part of the deforestation observed over the 2005-2013 period, but does not seem to be as important in the current deforestation processes. The marketing of wood to cities does not seem to play an important role.	less important role because the exploitation is counted as deforestation.	
Exploitation of firewood and non-marketed services	According to our surveys, in both dry and humid forests, the volumes consumed by households are low, and the market for these products is not very developed. As far as firewood is concerned, most of the wood harvested is dead wood.	Not mentioned as a DD factor in monitoring.	Analanjirofo, Alaotra Mangoro, Atsinanana, SAVA
Carbonization	Opinions differ in the Northeast: some believe that fuelwood (mostly consumed raw) would have a marginal impact overall in terms of degradation, and that the little charcoal consumed would come from eucalyptus plantations; others believe that fuelwood (consumed carbonized) would have a locally important impact (Atsinanana, Alaotra-Mangoro, Sava Regions) in terms of degradation.	Charcoal burning is globally a direct cause of DD according to the information collected during the monitoring carried out by LOFM and Methodology.	Alaotra Mangoro, Atsinanana
Fires	The Sofia, Analanjirofo and Alaotra-Mangoro regions in the humid forests are mainly affected by fires. Bush fires are very frequent and frequently cited by resource persons as drivers of deforestation. The causes of these fires are not well known. In decreasing order of importance, these include pastures regeneration, burning plots to be cultivated, cooking in the forest, cigarette butts left by smokers, charcoal grinders, the Dahalo, hunting, protests, acts of revenge and jealousy, and bee smoking.	Fires or fire passages have also been noted as important factors of deforestation, particularly in the Alaotra Mangoro Region. According to the sources, they are due to uncontrolled fires (too small a size of firewalls, fires made expressly without any explained reason in addition to those generated during slash-and-burn operations).	Alaotra Mangoro
Demographics	Migration increases population growth and pressure on the forests. These migrations can be due to the opening of illegal mines, illegal logging, and the search for fertile land. They are facilitated by the lack	According to the data collected by LOFM, migration phenomena generate significant deforestation because migrants resort to illegal	Analanjirofo, Alaotra Mangoro, Atsinanana, SAVA

	of clarity on land rights in the receiving areas and recurrent droughts in the sending areas.	artisanal mining, the practice of tavy, and illegal logging.	
Economic context	In the humid forest ecoregion, market growth, marketing and prices of agricultural products seem to have little influence on deforestation and degradation, as the majority of agricultural and forest products are self-consumed. The structural poverty of rural populations is often cited as an important underlying driver of deforestation, but the important role of certain urban "elites" in commercializing unsustainably harvested agricultural/forestry/wood products should not be forgotten. Finally, in dry and humid forests, the level of poverty is very homogeneous between zones. It does not explain why some areas are more deforested than others.	According to some resource persons, the isolation and low education level of the population are partly responsible for deforestation and forest degradation.	Alaotra Mangoro, SAVA
Technology	In the Analanjirofo, Sava, and southern Alaotra-Mangoro Regions, and to a lesser extent in the Atsinanana Region, the importance of unplowed and unweeded plots may reflect a strong influence of tavy on deforestation.	During the 2021 field surveys, it was mentioned that technology was brought to the village communities, but the follow-up of these agricultural development projects - which aimed to improve the population's standard of living - was non-existent. In addition, there was a lack of knowledge about household cash management and a lack of will to adopt better production behavior (techniques, improved seeds, cash management, etc.), which led to constant pressure on the forest resource through the expansion of crops, stagnant yields, and poor performance.	Analanjirofo, Alaotra Mangoro, Atsinanana, SAVA

The indirect causes of deforestation that were identified according to the ERPD were :

- **Demography and migration:**
  According to the ERPD, tavy traditionally takes place in secondary forests, but limited availability of land, population growth and migration can lead to an increase of tavy in primary forests. Migration may be due to the opening of illegal artisanal mines, illegal logging, and search for fertile lands, or agricultural opportunities in cash crops. Migration is a cultural tendency fostered by the lack of clear land tenure and land legislation. The density and distribution of the population were recognized as explanatory variables for deforestation. The saturation of irrigated valleys pushes the youngest and the landless people to forest areas.
  According to the interviews on 2021, demography and migration remain underlying causes of deforestation of the forests in the eastern part of Madagascar, as example: the case of the Zahamena forest managed by MNP were migration due to opening of artisanal mining is an important underlying cause.
  In the ERPD, it is mentioned that unfortunately, and as stressed by the International Organization for Migration (IOM, 2013): "The issue of internal migration in Madagascar is little known: little is known about the frequency, causes and consequences of migration. It is a relatively difficult phenomenon to observe and [...] there is a shortage of numerical data".

  The four regions studied by LOFM : Analanjirofo, Alaotra Mangoro, Atsinanana, SAVA were concerned by this indirect cause.

- **Economic Factors :**
  In the ERPD, it is said that the structural poverty among rural populations is a major underlying driving force behind deforestation, as rural populations are dependent on natural resources for their subsistence and local economy. But the lack of financial resources inhibits them from investing in sustainable practices. The social conditions in the ER-P area is described as a widespread poverty, a lack of economic opportunity, and reliance on tavy for basic subsistence.
  Three types of markets are known to foster deforestation and degradation in the ER-P area:
    - Agricultural products dedicated to export (e.g : vanilla, cloves and coffee ;
    - Precious wood ;
    - Mining and rare earth products.

  The situation remains the same during the monitoring period in the regions of Alaotra Mangoro and SAVA in general.
  The four regions studied by LOFM : Analanjirofo, Alaotra Mangoro, Atsinanana, SAVA were all concerned by the next defined underlying causes:

- **Technological factors:**
  The ERPD explains that the agricultural intensification practices are currently too infrequently implemented to play a role in reducing deforestation. Meanwhile, the productivity of traditional agriculture systems (tavy) is stagnating or even declining and intensification practices are not widely observed. Thus, it can be considered that the lack of technological advances in the agricultural sector contributes to deforestation in all areas of the ER-P. Populations rely on slash-and-burn to increase fertility of soils. This situation is still remaining the same.
- **Policies and Institutional Factors:**
  Policies and institutional factors was listed as an underlying cause of deforestation in the ER-P zone. This is still remaining an impoortant underlying cause during the monitoring perdiod. The ERPD precised that the limited human and financial resources, the absence of a formalized arrangements for management between NGOs who work intensively in forest areas, and Madagascar National Parks, corruption, conflicts of interest, and the difficult implementation of the system for granting tender-based logging permits all contribute to weak forest governance, particularly at local levels.
- **Property and land tenure legislation:**

In the eastern humid forest ecoregion, as the ERPD mentions and according to the interviews for the monitoring period, the traditional land tenure systems have undergone major changes over the last decade. The loss of power of village and traditional leaders, the rise of land transactions, the creation of local tenure offices (BIF) and the introduction of land certificates have altered the traditional land tenure systems. Customary tenure rules that often do not apply to forests now coexist with the current state law.

According to the ERPD, the effects of these changes are diverse in terms of their impact on deforestation and forest degradation. They can be accelerators (e.g. development of land transactions and incentives for land grabbing for future speculation) or mitigating factors (e.g. certificates which secure tenure for farmers and encourage them to invest in the long-term management of soil fertility) of deforestation and degradation.
The poorest households and migrants tend to employ strategies of agricultural colonization through deforestation in order to secure land. This agricultural colonization is still observed and the phenomenon is generalized in the in the ER-P area. This is an important underlying driver of deforestation and the lack of recognition of a forest land tenure regime exacerbates the situation.

- **Culture:**
  The ERPD mentions that culture is an underlying cause of deforestation. Rural populations perceive the forest primarily as a reserve of arable land or pasture. Further surveys indicate that most households are aware of the benefits of reducing deforestation If intact or relatively intact forests are deforested, it seems that this is sometimes done "reluctantly".
  Even though individual behavior can sometimes explain deforestation (no respect for protected areas, resistance to change, individualistic attitude) (Salva Terra, 2017). Discontent with local or central governments may also have some explanatory power for the starting of fires. Competition over land between ethnic groups linked with migratory phenomena explains some races for land clearing.
  Finally, sacred forests and taboos provide protection to forests, but the concerned areas are too small to have a tangible impact and immigrants may be less prone to heed the established local belief systems.
  The situation is the same during the monitoring period.
- **Environmental Suitability:**
  The localization of deforestation is correlated with several physical variables : altitude, slope, soil fertility and forest fragmentation.
  ▪ Altitude: estimates of the most affected areas by deforestation among eastern rainforests vary between 400 and 1,000 m, mostly because the majority of low land forest has already disappeared (Salva Terra 2017).
  Slope: local communities practice tavy on slopes less than 40°.
  Soil fertility: although fertile soils are deforested first, the expansion of the frontier region is slower.
  ▪ Forest fragmentation: isolated forest patches are most likely to be deforested.

  The areas that farmers target can be described in descending order of priority for cultivation by ease and productivity (high priority first)—the plains or shallows, valleys and then hills.
  The criteria for choosing the land to be cleared are, in descending order—soil fertility, the absence of weeds and the presence of water (Salva Terra 2017).

In the context of Madagascar, to reliably prioritize and quantify the impacts of each driver of deforestation and degradation in the entire program area has not been feasible with the available data and the plurality of drivers, each of which being difficult to spatialize and map. It is however clear that all drivers are linked and exacerbated by poverty. The listed underlying causes of deforestation in the ERP-D are still valid for the monitoring period (2020).

Displacement of activities (leakage)

Regularly monitor (based on available data) the deforestation rate in the remaining areas of the 5 affected regions outside of the ERP accounting area, and if a significant increase in the deforestation rate occurs that is related to the ERP (e.g., displacement), consider potential actions to address the causes of that deforestation.

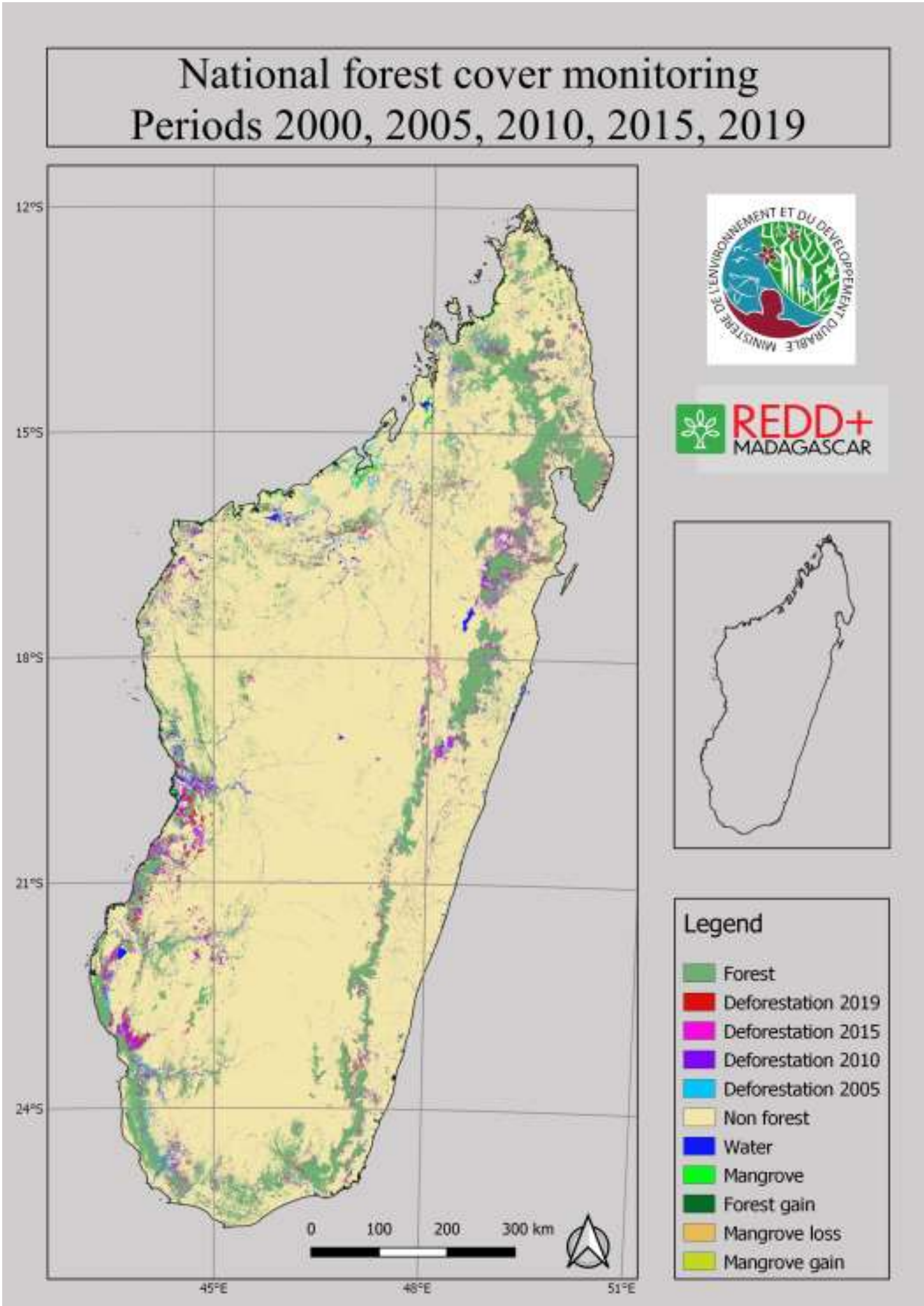
Action Item

The ER-P is designed so that all activities implemented are discussed and planned at the commune and landscape level with the participation of all stakeholders.
Only large-scale projects could result in displacement risk. The ER-P will put procedures in place to ensure that design phase consultations with the affected communes are undertaken and that a displacement analysis and mitigation strategy is developed.
In addition, the ER program incorporates a set of activities aimed at increasing agricultural productivity (AD1), diversifying income from natural resources (AD2), and strengthening agricultural value chains to increase income from agricultural activities (i.e., without increasing production) (AI1). These activities will increase the efficiency of existing agricultural land use, avoiding the need for displacement caused by mitigation activities within the forest sector (FD1, FD2, FI1).

The risk of displacement due to emigration will be monitored during each project design phase (and thus included in the Regional REDD+ Activity Plan), and a specific strategy will need to be designed to anticipate potential negative impacts.

Leakage monitoring (in areas outside the initiatives) is done every 2 years, with an assessment of displacement outside the initiatives. Updated forest cover maps and satellite images (activity data from Collect Earth) will be used for this purpose. LOFM and Methodology will implement this leakage monitoring.

The national deforestation map between 2000 to 2019 is as follows :



Map 3 : Analysis of historical deforestation between 2000 to 2019 (2000-2005, 2005-2010, 2010-2015, 2015-2019 periods)

2. **System for measuring, monitoring and reporting emissions and removals occurring within the monitoring period**

2.1 Forest Monitoring System

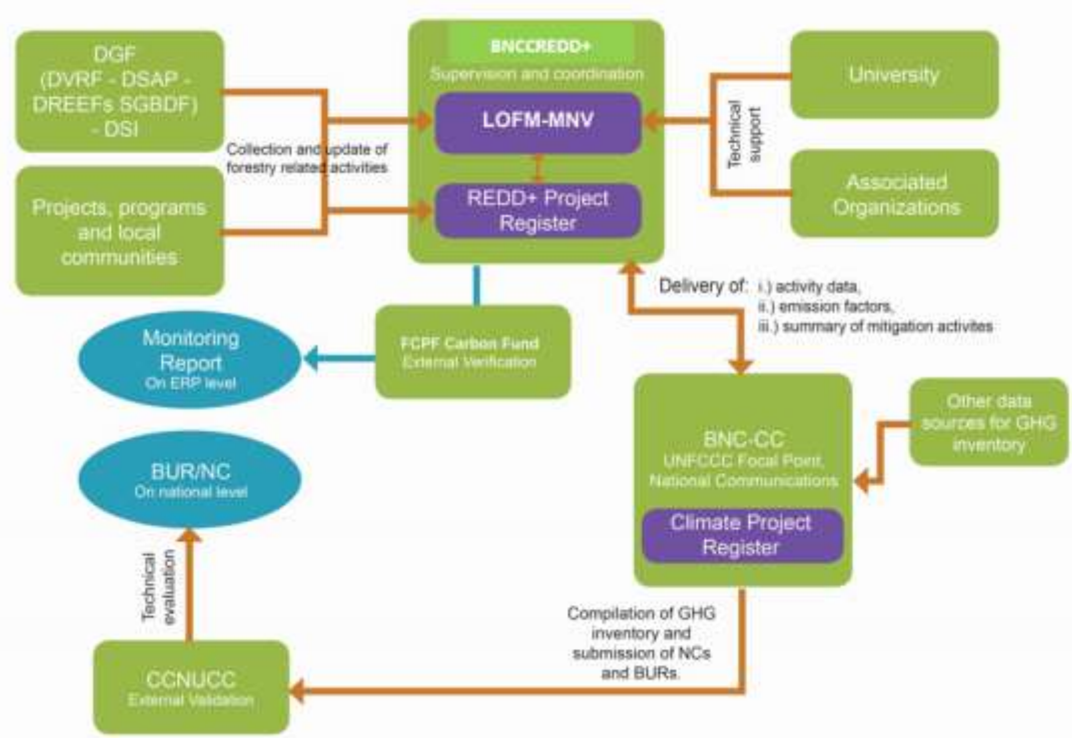
Table 5: Causes of deforestation and forest degradation

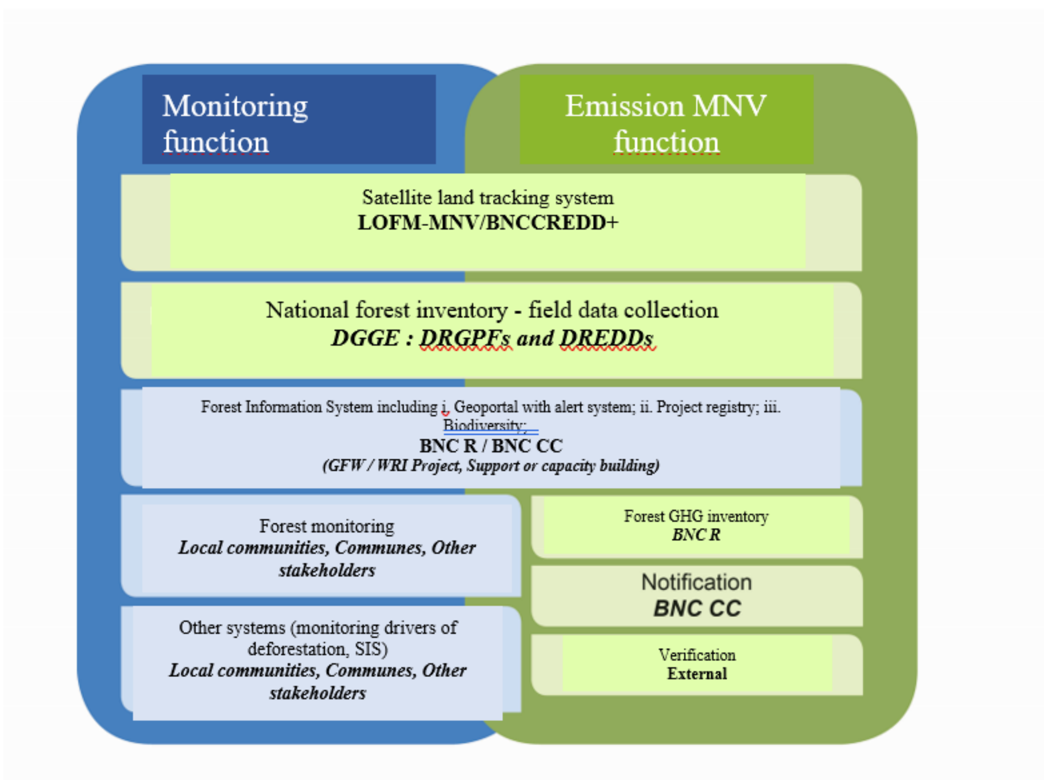
Themes		State of play
Organizational structure, responsibilities, skills		The Government of Madagascar is in the process of establishing a National Forest Monitoring System (NFMS) that also performs the monitoring and reporting functions of the country's ER program for future emissions and potential emission reductions. The monitoring system is based on the following key elements: ▪ BNCCREDD+ (National Office of Climate Change and REDD+) is a Direction at the Ministry in charge of Environment and Forest. This national office coordinates climate changes and the Reduction of the Emissions from Deforestation and Forest Degradation (BNCCREDD+). This structure is responsible for supporting the coordination of its initiatives and actions relating to climate change and the Emission Reduction mechanism hees to Deforestation and Forest Degradation (REDD+). These actions aim to support: the promotion of a restful economy adapted to the effects of climatic changes; the promotion of sustainable development with low carbon emissions and other greenhouse gases emissions (GHG) causing climate change; the reduction of emissions linked to deforestation and the degradation of forests by the promotion of the REDD+ mechanism. The activities of the National Office aim to the development of the sale of carbon and the guarantee of the fair sharing of benefits, as well as the promotion of sustainable financing mechanisms to combat against climate change. The BNCCREDD+ assumes overall responsibility for future land use change assessment and ERP monitoring report development. *There are two (02) Divisions within BNCCREDD+ namely the Madagascar Forest Observation Laboratory (LOFM or “Laboratoire d’Observation des Forêts de Madagascar”) and Methodology. The two Divisions each have distinct roles and responsibilities, as follows **Methodology Division** **<u>Roles and responsibilities</u>** - Design, implement and ensure the realization of national forest inventory methodologies - Ensure the implementation of Greenhouse gas inventories for the forestry sector - Establish the calculation methods of the Forests Reference Emission Levels (FREL) and proceed to their evaluation - Establish the methodological standards for the determination of Emission Factors and make the calculations - Ensure the measurement of carbon performance at the scale of REDD+ Programs and Initiatives - Participate in the calculation and reporting of carbon performance based on a transparent and reliable methodological process in coordination with the LOFM **Madagascar Forest Observation Laboratory Division (LOFM)** **<u>Roles and responsibilities</u>** - Ensure cartographic production and generation of forest statistics with protocols and manuals for each process

		- Ensure the adoption of the Land Use and Occupancy classification systems and forest definitions as national standards - Develop, formalize and popularize standard tools for monitoring forest cover (national grid...) and their guides for use by third parties - Have a cartographic database/metadata, satellite images, statistics, reports - Develop and implement the Satellite Land Monitoring System - Collect, ensure and control the quality of data on land use change and forest area, and perform analyses - Conduct spatial analyses including descriptive causes of deforestation and degradation - Monitor changes in national forest cover, at administrative scales as needed (deforestation rate per Commune ...) and in Programs and Initiatives - Store and make available information to meet reporting obligations at both national and international levels and for decision making by decision makers - Contribute to the measurement of carbon performance by making available information on forest cover dynamics - Participate in the calculation and reporting of carbon performance based on a transparent and reliable methodological process in coordination with the Methodology To ensure its operation, the LOFM and the Methodology Division work in collaboration and have seven (07) staff, namely - One (01) Head of Laboratory who coordinates the activities of the Laboratory - A Methodology Manager who ensures the follow-up of the forest inventory, the calculation of emission factors and performance - Five (05) operators who ensure activity data collection, data processing and analysis, mapping of Land Use and Occupancy (LUO) The work carried out at LOFM follows well-defined standard procedures or Standard Operating Procedures (SOPs): - The SOP on stratification map creation (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-stratification#) - The SOP on sampling (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-lechantillonnage#) - The SOP on data interpretation (response system) (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-linterpretation-des-donnees#) - The SOP on data collection (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-collecte-des-donnees#) - The SOP on data Analysis (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-lanalyse-des-donnees#) Remote sensing analyses are conducted by a remote sensing laboratory that was established in 2018 under the mandate of BNCCREDD+. This laboratory named "Laboratoire d'Observation des Forêts de Madagascar" (LOFM, Forest Observation Laboratory of Madagascar) determined the ER Program activity data (baseline and monitoring period) and also determines the activity data to monitor emissions and removals at the national scale.

BNCCREDD+ hosts a REDD+ project registry (Section 6) that provides a standardized data flow of REDD+ projects in the ER Program area and at the national scale. The data includes monitoring results, loss events, and carbon sales to avoid double counting.
The DGGE (including the DRGPF which is responsible for implementing the national forest inventory) has provided new inventory data to the BNCCREDD+.
Local communities and so-called REDD+ "initiative" projects are sources of information on performance, illegal logging activities, loss events, poaching, and irregularities in the REDD benefit-sharing process.
Community-based monitoring activities exist in areas where government presence is weak.
Studies conducted in the Eastern humid forests funded by the World Bank and FCPF in 2017 with Salva Terra, identified drivers of deforestation and forest degradation.
Deforestation and degradation monitoring activities conducted by LOFM on the year 2021 for the monitoring period 2020 were based on interviews, focus groups, and field visits within the forests of the initiatives' areas and in the so-called buffer zone of the initiatives' boundary. This was done for a sample of REDD+ initiative areas in Andasibe, Ambatondrazaka, Maroantsetra and Masoala.
These areas have different intensities of deforestation detected on the stratification map: a high intensity of deforestation in Maroantsetra (Masoala and Makira) in the extreme northeast of the ER program, within the initiative areas; severe deforestation in the Andasibe region (Analamazaotra, Mantadia) part of the exchange program; and a lower intensity of deforestation found in Zahamena, Ambatondrazaka region according to the stratification map pre-drawn by the LOFM for the year 2020.
BNCCREDD+ prepares and compiles the results of the measurement, monitoring and reporting activities into the monitoring report submitted to the FCPF for external verification.

The organizational structure of the monitoring, reporting, and verification system (i.e., those functions of the NFMS that are limited to accounting for emissions/removals) is illustrated in the figure below.



Selection and management of GHG data and information	Methods and standards for data generation, storage, aggregation and reporting	The ER Program's Forest Monitoring System (FMS) is integrated with the New National Forest Monitoring System (NFMS). This NFMS is established in accordance with Copenhagen Decision 4/C.15 and has two main functions: a monitoring function and a measurement, reporting and verification (MRV) function. The monitoring function is used to monitor legal compliance, safeguards and other aspects of the ER Program. Monitoring data are generated according to standard operating procedures and correspond to the ER Program approaches in terms of forest definition, forest type definition, activity selection, pre-processing and processing methods, emission factors, change category uncertainties and overall uncertainties, etc. The data is stored and published on the MEDD website Ministère de l'Environnement et du Développement Durable | République de Madagascar In this link are available the following documents : - Legal documents (title transfer and access to the Carbone revenue - Safeguards documents - MRV documents - Land use map and processes - Activity data and map (in the MNV Standart tab), which is an inherent part of the NFMS. Inventory results are stored in the same way. This approach ensures that the data is stored and is publicly available. **Structure of the NFMS** The MRV function of the NFMS is strictly related to the estimation, reporting and verification of GHG emissions and removals.  Data processing :

		The REDD + Initiatives and Programs Information System or SIIP is a secure computer system that aims to assist the management and monitoring of REDD+ initiatives and programs. It collects, saves, processes, classifies and disseminates all information related to the management, monitoring and evaluation of REDD+ activities and its actors. The SIIP ensures transparency in the implementation of REDD+ activities, the implementation of benefit sharing and the monitoring of performance generated by REDD+ Initiatives and Programs. The SIIP consists of a set of (i) data, (ii) procedures, (iii) processing and (iv) reporting. Its mandate is as follows: - Validate and formalize all information on REDD+ initiatives and programs; - Centralize, compile and process information provided by the different actors; - Manage the confidentiality and security of REDD+ data; - Establish traceability and alert of pending situations such as pending complaints, lack of financial reporting, or others; - Share decision information according to the needs of different actors as well as accountability information for REDD+ governance structures, in public or private form; - Provide information for the evaluation of the performance of each actor within each initiative; - Disseminate information on the performance of REDD+ initiatives and programs as well as the spatialization of REDD+ funding; - Ensure consistency between information on ER performance and the creation of "carbon stocks" through the Transactional Registry. Emissions by sources and removals by sinks measured, monitored, and reported by FMS are consistent with those reported by the RL (as required by Criterion 14 of the Methodological Framework). This was done through four main principles: ▪ Consistent scope: The same scope in terms of geographic area, REDD+ activities, carbon pools, and greenhouse gases retained from the RL (CF MF indicator 14.1); ▪ Activity Data (AD): Data on the extent of human activity resulting in emissions or removals during a given time period were measured and monitored using the same methods used to define it in the RL (CF MF Indicator 14.2); ▪ Emission factors (EFs) and default values: The same EFs and default values used for the RL were s used in the estimation of GHG emissions by sources and removals by sinks (CF MF Indicator 14.3); ▪ GHG accounting: the same equations, calculation procedures, and QA/QC as used for the RL were used (CF MF Indicator 14.1). The only parameters being changed with respect to the RL are the activity data.
Processes for collecting, processing, consolidating, and reporting GHG data and information - Systems and processes that ensure the accuracy of data and information - Design and maintenance of		The overall measurement, monitoring, and reporting process includes all Earth Observation (EO) data collection operations, Quality Assurance (QA) operations, and final reporting. Data collection and processing were performed to produce activity data in the form of: subcategory/land use strata conversion area (A(j, i), A(i,j)). Key specifications for data collection and processing are shown in Section 3.2. Once the emission reductions have been calculated, they will be reported with all information provided in a transparent manner demonstrating that the principles outlined in Section 9.1 have been followed. Any interested organization or individual can find the information on the web (BNCCREDD website). The system and processes that support the Forest Monitoring System are in place: - Satellite Land Monitoring System - MRV

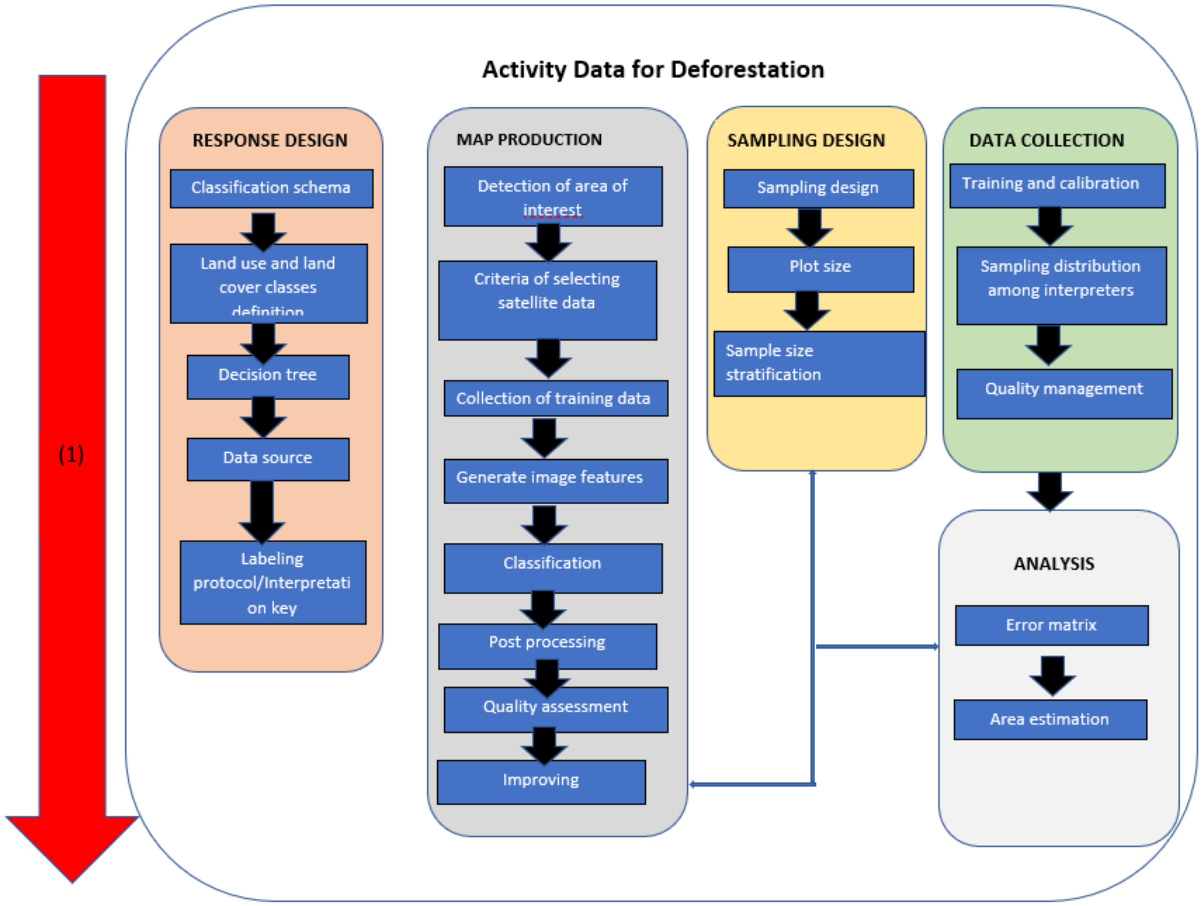
the Forest Monitoring System		As stated previously in the paragraph on the organizational structure, responsibilities, skills, the work carried out within the LOFM follows well-defined standards of Procedures or Standard Operating Procedures (POS), these are: - The SOP on the creation of the stratification map (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-stratification#) - The SOP on sampling (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-lechantillonnage#) - The SOP on data interpretation (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-linterpretation-des-donnees#)(response design) - The SOP on data collection (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-collecte-des-donnees#) - The POS on data analysis (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-lanalyse-des-donnees#) Each POS has its own objective, namely: - For the SOP 0 concerning the Mapping of Land Use and Occupation changes for stratification; it is to detail the procedures for creating a map of land use and cover and these changes in order to prepare a stratified random probability sample. - SOP1 on Sampling Design preparation is used to establish a spatially referenced, probability-based and geographically balanced sampling design for area estimation in terrestrial surveys. It is applicable for monitoring with stratified sampling. -The SOP on the forest inventory guidelines (https://www.environnement.mg/?wpdmpro=guide-dinventaire-forestiers#) - SOP2 for response design explains how to assign labels (e.g.: land cover/land use class) to a sample unit. The response plan allows for the best available classification of change for each sampled spatial unit and contains all the information needed to replicate the process of assigning a label to the sampled unit. The response design defines an objective procedure that interpreters can follow that reduces interpreter bias. - SOP3 gives details on data collection and details how to set up and run data collection for sample-based visual interpretation primarily using remote sensing data to collect sample information. Finally, SOP4 is about data analysis and provides area estimates and their uncertainties through the combined use of reference data and maps. QA/QC procedures are applied, specifically for the collection and updating of activity data, namely: - During the creation of the stratification map, a quality assessment of the classification is carried out using the confusion matrix, and by calculating the errors of omission and errors of commission. What is important to note is the skip and commission value for the change class. These numbers should be small enough to use the map (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-stratification#). - When collecting activity data in the Collect Earth tool: In general, once you fill in the information on a plot, you have to check the information included. Especially if the assigned change of cover and the classes of the two dates studied are logical. You have to have reasoning and correspondence. An operator other than the one who performed the data collection retests a random sample of 20 percent of the total number of samples during Quality Assurance. For quality control, 5% of the added samples of all change classes and those with low confidence are reanalyzed by the group (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-collecte-des-donnees#). - During data analysis: The Laboratory and Methodology Manager, in coordination with the analysts, checks that the calculations comply with SOP number 4 on data analysis, including the script used for the calculations. Then they cross-check the estimates with previously reported estimates for the same classes. Estimates are further cross-checked and compared to estimates reported by other sources (e.g. Global Forest Resources Assessment, National Greenhouse Gas Inventory, UNFCCC reports, Global Forest Watch ...) (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-lanalyse-des-donnees#).

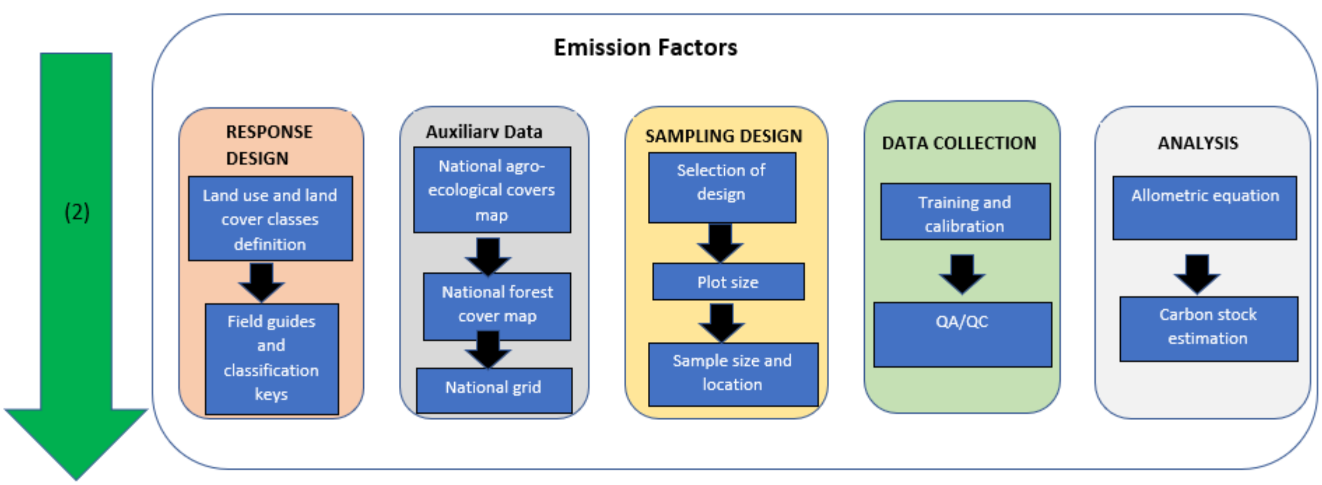
		The forest inventory guidelines are available on REDD+ website (https://www.environnement.mg/?wpdmpro=guide-dinventaire-forestiers#)
The role of communities in the Forest Monitoring System;		Communities participate in the forest monitoring system through patrols. They can provide sources of information on the history of REDD+ intervention sites. They can also work closely with the agents responsible for monitoring (CRR, BNCCREDD agents, deconcentrated MEDD services, DREDD) during the forest monitoring phase for data collection, data verification…
The use of and consistency with technical procedures operational in the country, and their consistency with the National Forest Monitoring System.		The basic technical procedures (activity data collection, NERF/NRF calculations, emission reductions) are applied at the national level, thus uniform in the country. The standard national process and procedures are enforced by the Decree on the regulation of access to the forest carbon market. The tools and methods used are consistent with the existing national forest monitoring system.

2.2 Measurement, monitoring and reporting approach

2.2.1 Line Diagram

The following figure illustrates the workflow for calculating emission reductions during the monitoring period. Note that this workflow, including the reporting phase, is implemented by the LOFM Division and MRV of BNCCREDD+.


Activity Data for Deforestation
(1)
RESPONSE DESIGN
Classification schema
Land use and land cover classes definition
Decision tree
Data source
Labeling protocol/Interpretati on key
MAP PRODUCTION
Detection of area of interest
Criteria of selecting satellite data
Collection of training data
Generate image features
Classification
Post processing
Quality assessment
Improving
SAMPLING DESIGN
Sampling design
Plot size
Sample size stratification
DATA COLLECTION
Training and calibration
Sampling distribution among interpreters
Quality management
ANALYSIS
Error matrix
Area estimation


Emission Factors
(2)
RESPONSE DESIGN
Land use and land cover classes definition
Field guides and classification keys
Auxiliary Data
National agro-ecological covers map
National forest cover map
National grid
SAMPLING DESIGN
Selection of design
Plot size
Sample size and location
DATA COLLECTION
Training and calibration
QA/QC
ANALYSIS
Allometric equation
Carbon stock estimation

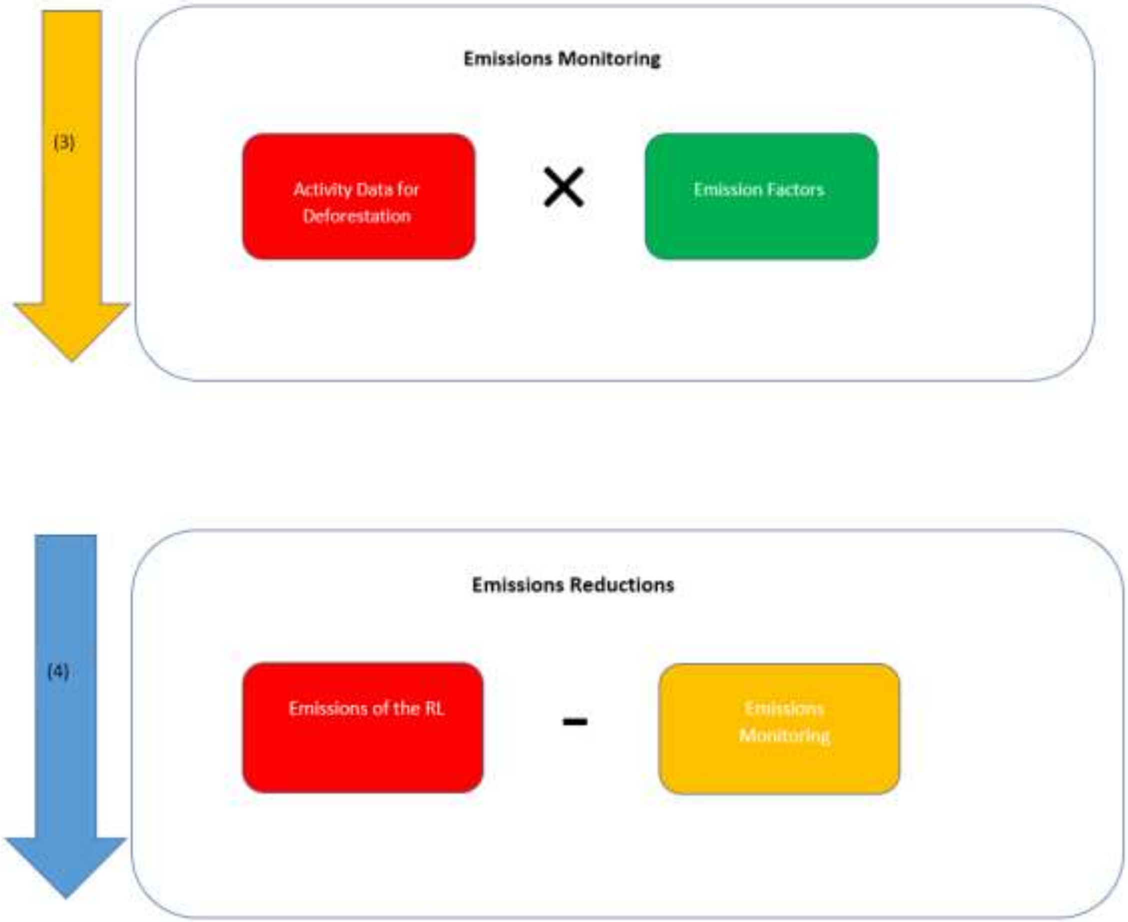


Figure 1 : Workflow on emission reduction calculation

2.2.2 Calculation (link : https://drive.google.com/file/d/1QQtpS_4RpcF9rKIARd-eBE0YMeRa5H4C ; Biomasse Madagascar, https://drive.google.com/file/d/1Bgm0DqFAFN7zIeeOrGHhYgDaUlycvMa1; https://www.environnement.mg/?wpdmpro=standard-doperation-pour-lanalyse-des-donnees# ; (PERR-FH. 2015 ; DRGPF.2021)

2.2.2.1 EMISSION REDUCTIONS

In order to execute this operation of the process, the same IPCC methods and equations described in Chapter 8.3 will be used to estimate GHG emissions in the monitoring period.
The following equations would be applied to estimate the Emission Reductions in year t:

$$ER_t = RL_t - \mathrm{GHG_t} \quad \textbf{Equation 1}$$

Where:

ER_t	=	GHG emission reductionS; tCO_2e $year^{-1}$.
RL_t	=	GHG emissions of the RL in year T; tCO_2e $year^{-1}$.
GHG_t	=	Monitored GHG emissions in year T, tCO_2e $year^{-1}$

2.2.2.2 REFERENCE LEVEL (RL_t)

The RL estimation may be found in Annex 4, Section 8.3.

2.2.2.3 MONITORED EMISSIONS (GHG_t)

$$GHG_t = \sum_i \Delta C_{B,t,i} + \Delta C_{DOM,t,i} + \Delta C_{SOC,t,i} + L_{fire,t,i}$$ **Equation 2**

B Where:

$\Delta C_{B,t,i}$	=	Changes in carbon stocks in biomass from REDD+ activity i in year t; tCO_2e year^{-1}.
$\Delta C_{DOM,t,i}$	=	Changes in carbon stocks in Dead wood and Litter from REDD+ activity i in year t; tCO_2e year^{-1}.
$\Delta C_{SOC,t,i}$	=	Changes in Soil Organic Carbon from REDD+ activity i in year t; tCO_2e year^{-1}.
$L_{fire,t,i}$	=	Non-CO2 emissions from fire in REDD+ activity i in year t; tCO_2e year^{-1}.

Equations for the estimation of the different activities, deforestation, forest degradation and enhancement of carbon stocks is provided in the next sections.

Deforestation

Changes in carbon stocks in biomass

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category (ΔC_{B_t}) would be estimated through the following equation:

$$\Delta C_{B_t} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$ **Equation 2**

Where:

ΔC_{B_t}	Annual change of total biomass carbon stocks during the period, in tC per year;
ΔC_G	Annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tC per hectare and year;
$\Delta C_{CONVERSION}$	Initial change in carbon stocks in biomass on land converted to other land-use category, in tC per hectare and year; and
ΔC_L	Annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tC per hectare and year.

Following the recommendations set in chapter 2.5.1.1 of the GFOI Methods Guidance Document for applying IPCC Guidelines and guidance in the context of REDD+*, the above equation will be simplified and it will be assumed that:

- The annual change in total biomass carbon stocks (ΔC_B) is equal to the initial change in carbon stocks ($\Delta C_{CONVERSION}$);

Considering equation 2.16 of the 2006 IPCC GL for estimating ($\Delta C_{CONVERSION}$) the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta C_{B_t} = \sum_{j,i} \left(AGB_{Before,j} x(1+R_j) - AGB_{After,i} x(1+R_i)\right) \text{ x CF x} \frac{44}{12} \times A(j,i)$$ **Equation 3**

Where:

$A(j,i)$ Area of forest converted from forest to non forest during the monitoring period, in hectare per year. In this case, four possible conversions are possible:

- **Primary forest to non-forest (DPF);**
- **Disturbed Forest to Non-Forest (DDF);**
- **Secondary Forest to Non-Forest (DSF);**
- **Agroforestry to Non-Forest (DAF);**
  Plantations to Non-Forest (DPL);

The description of this parameter may be found in **Section 3.2.**

* https://www.reddcompass.org/mgd/resources/GFOI-MGD-3.1-en.pdf

$AGB_{Before,j}$ Aboveground biomass of forest type j before conversion, in tons of dry matter per ha. This can be the aboveground biomass of the following two types of forest:

- **Primary forest (PF);**
- **Disturbed Forest (DF);**
- **Secondary Forest (SF);**
- **Agroforestry (AF);**
- **Plantations (PL);**

The description of this parameter may be found in **Section 3.1. Error! Reference source not found.**

Rj ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in ton d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to:

- **0.2** is the default for tropical moist deciduous forest when aboveground biomass is <125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for Secondary Forest and Agroforestry.
- **0.24** is the default for tropical moist deciduous forest, >125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for primary forest and disturbed forest.
- **3.35** is the root shoot ratio of Eucalyptus plantations according to RAZAKAMANARIVO et al. (2013). This is the case for Plantations.

$AGB_{After,i}$ Aboveground biomass of non-forest type I after conversion, in ton dry matter per ha. This is the aboveground of **non-forest (NF)**.

The description of this parameter may be found in **Section 3.1. Error! Reference source not found.**

R_i ratio of below-ground biomass to above-ground biomass for a specific vegetation type i, in ton d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to:

- **0.2** is the default for tropical moist deciduous forest when aboveground biomass is <125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for non-forest.

CF Carbon fraction of dry matter in tC per ton dry matter. The value used is !:

- **0.47** is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.

$44/12$ Conversion of C to CO_2

Changes in carbon stocks in Dead wood and Litter

Considering equation 2.23 of the 2006 IPCC GL for estimating ΔC_{DOM}, the change in dead organic matter carbon stocks could be expressed with the following equation.

$$\Delta C_{DOM,t} = \frac{(C_n - C_o)x\ A(j,i)\ x \frac{44}{12}}{T_{on}}$$ **Equation 4**

Where:

$A(j,i)$ area undergoing conversion from old to new land-use category, ha. This is the same as parameter $A(j,i)$ above. The description of this parameter may be found in **Section 3.2.**

C_o dead wood/litter stock, under the old land-use category, tonnes C ha-1.

For dead wood it will have different values for each of the following forests:

- **Primary forest (PF);**
- **Disturbed Forest (DF);**
- **Secondary Forest (SF);**
- **Agroforestry (AF);**
- **Plantations (PL);**

For Litter, a default value for tropical broadleaf forests of **2.1** tC/ha has been used. This has been sourced from 2006 IPCC GL, TABLE 2.2, Volume 4, Chapter 4.

C_n	dead wood/litter stock, under the new land-use category, tonnes C ha-1. It has been assumed that this is **zero**.
T_{on}	time period of the transition from old to new land-use category, yr. The Tier 1 default is **1 year** for carbon losses, so it has been assumed one year.
$44/12$	Conversion of C to CO2

Changes in Soil Organic Carbon

Since in the ER program area there are only mineral soils, considering equation 2.25 of the 2006 IPCC GL for estimating ΔC_{SOC}, the change in soil organic carbon could be expressed with the following modified equation.

$$\Delta C_{SOC,t} = \frac{\sum_{j,i}\left(\left(SOC_{Before,j} - SOC_{After,i}\right) \times \frac{44}{12} \times A(j,i)\right)}{D}$$ **Equation 5**

Where:

$A(j,i)$	land area of the stratum being estimated, ha. This is the same as parameter $\boldsymbol{A(j,i)}$ above. The description of this parameter may be found in **Section 3.2.**
$SOC_{Before,j}$	the reference carbon stock, ton C ha^{-1} for forests. It has been assumed the same value for the following forest types. • **Primary forest (PF);** • **Disturbed Forest (DF);** For plantations and Agroforestry it is not accounted for.
$SOC_{After,i}$	the carbon stock, ton C ha^{-1} for **non-forest (NF).**
$44/12$	Conversion of C to CO2

Non-CO2 emissions from deforestation

Following the Equation 2.27 of Volume 4 of the 2006 IPCC GL, GHG emissions from forest fires are estimated with the following equation:

$$L_{fire,t} = A x M_B x C_f x G_{ef} x 10^{-3}$$ **Equation 6**

Where :

A	area burnt, ha, which is equivalent to $A(j,i)$ Area of forest converted from forest to non-forest during the monitoring period, in hectare per year. The description of this parameter may be found in **Section 3.2.** This could be the following conversions : • **Primary forest to non-forest (DPF);** • **Disturbed Forest to Non-Forest (DDF)** • **Secondary Forest to Non-Forest (DSF)** • **Agroforestry to Non-Forest (DAF)** • **Plantations to Non-Forest (DPL)**
M_B	mass of fuel available for combustion, tonnes ha^{-1}. This is equivalent to the biomass prior to conversion $\boldsymbol{AGB_j}$**.** This is the aboveground biomass in forest areas as afforestation/reforestation does not involve burning prior to conversion.
C_f	combustion factor, dimensionless. This is equal to: • **0.5** for primary forest, as it is the value for primary tropical forest (slash and burn) according to 2006 IPCC GL Table 2.6 • **0.55** for modified natural forest, as it is the value for secondary tropical forest (slash and burn) according to 2006 IPCC GL Table 2.6
G_{ef}	emission factor, g kg^{-1} dry matter burnt. This is equal to: • **6.8** for CH4 as it is the value for tropical forest according to 2006 IPCC GL Table 2.6

- **0.2** for N2O as it is the value for tropical forest according to 2006 IPCC GL Table 2.6

In order to convert these GHG emissions to $tCO2_e$, GHG emissions from CH4 and N2O are multiplied by the Global Warming Potential for both gases (GWP), so the equation would be as follows:

$$L_{fire,t} = A(j,i) x AGB_{Before,j} x C_f x (G_{ef_{ch4}} x GWP_{CH4} + G_{ef_{N2O}} x GWP_{N2O}) x 10^{-3}$$ **Equation 7**

Where :

GWP_{CH4}	Global Warming Potential of CH4, = 28
GWP_{N2O}	Global Warming Potential of N2O, = 265

Values from the last AR5 are used as recommended, all the numbers updated accordingly

Global Warming Potential (GWP) of CH4 and N2O value can be found on the link .
https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf .

<u>Reducing Emissions from Degradation / Forest Land remaining Forest Land</u>

Following the recommendations set in chapter 2.5.1.2 of the GFOI Methods Guidance Document, GHG emissions from degradation will be estimated by taking "account of long-term reductions of carbon densities due to transitions between forest strata and sub-strata, and within the strata and substrata affected by human activity (i.e. MNF and planted forests)". In essence this means, by multiplying activity data of transition between different types of forest by the difference in average carbon stocks.

Considering equation 2.16 of the 2006 IPCC GL for estimating $\Delta C_{CONVERSION}$ and considering 2.8 b for the estimation of carbon stocks, the change of biomass stocks could be expressed with the following equation.

$$\Delta C_{B,t} = \sum_{j,i} \left(AGB_{Before,j} x (1 + R_j) - AGB_{After,i} x (1 + R_i) \right) x \ CF \ x \frac{44}{12} \times A(j,i)$$ **Equation 8**

Where:

$A(j,i)$ Area of forest converted from primary forest to modified natural forest – disturbed forest or to plantation during the monitoring period, in hectare per year. The description of this parameter may be found in **Section 3.2.**This could be the following conversions:

- **Primary forest to Disturbed Forest (D-PF DF);**
- **Primary forest to Agroforestry (D-PF AF);**
- **Primary forest to Plantations (D-PF PL);**
- **Disturbed Forest to Agroforestry (D-DF AF)**
- **Disturbed Forest to Plantations (D-DF PL)**

$AGB_{Before,j}$ Aboveground biomass of forest type j before conversion, in ton of dry matter per ha. This is the aboveground biomass of **Primary forest (PF)** or **Disturbed Forest (DF).** The description of this parameter may be found in **Section 3.1.**

Rj ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in ton d.m. below-ground biomass (ton d.m. above-ground biomass. This is equal to:

- **0.24** is the default for tropical moist deciduous forest, >125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for <u>primary forest and disturbed forest</u>.

$AGB_{After,i}$ Aboveground biomass of non-forest type I after conversion, in ton dry matter per ha. This is the aboveground of **Disturbed Forest (DF)** or **Agroforestry (AF)**. In the case of **Plantation (PL)** this is assumed to be zero so as to comply with the requirements on Safeguards of the Cancun agreements. The description of this parameter may be found in **Section 3.1.**

R_i ratio of below-ground biomass to above-ground biomass for a specific vegetation type i, in tonne d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to:

- **0.24** is the default for tropical moist deciduous forest, >125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for primary forest and disturbed forest.
- **0.2** is the default for tropical moist deciduous forest when aboveground biomass is <125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for Agroforestry.

CF Carbon fraction of dry matter in tC per ton dry matter. The value used is:

- **0.47** is the default for tropical forest as per IPCC AFOLU guidelines 2006, table 4.3.

$44/12$ Conversion of C to CO2

Enhancement of carbon stocks in new forests / Land Use Change from non-Forest Land to Forest

Following the recommendations set in chapter 3.1.4 of the GFOI Methods Guidance Document, enhancement of carbon stocks in afforestation/reforestation will be estimated by multiplying the activity data by the yield tables or growth curves in the generation of changes in carbon density through time on afforested/reforested lands. Since there are no such tables in Madagascar in regenerated forest, it will be assumed that afforested/reforested lands take 15 years to reach the status of secondary forest. This is seen as a better option than using averages, which is the alternative proposed in Chapter 3.14 of GFOI which would be a source of bias.

Therefore, the annual change in carbon stocks would be estimated as follows:

$$\Delta C_{B,t} = \sum_{j,i} \frac{\left(AGB_{Before,i} - AGB_{After,j}\right)}{\text{Years growth}}\, x(1+R)x\; CF\; x\frac{44}{12} \times A(i,j)$$ **Equation 9**

Where:

ΔC_B Change of total carbon stocks during the monitoring period, in tC per hectare, per year.

$A(j,i)$ Annual conversion from non-Forest Land use i to forest type j (planted forest or modified natural forest). The description of this parameter may be found in **Section 3.2.** Area of forest converted from non-forest to forest during the monitoring period, in hectare per year. In this case, it would be :

- **Non-forest to Secondary Forest**
- **Non-Forest to forestry**

$AGB_{Before,i}$ Aboveground biomass of non-forest type i before conversion, in ton dry matter per ha. In this case, it would be the aboveground biomass of **non-forest (NF)**. The description of this parameter may be found in **Section 3.2.**

$AGB_{After,j}$ Aboveground biomass of forest type j after conversion, in ton of dry matter per ha. The description of this parameter may be found in **Section 3.1.** In this case, it would be the aboveground biomass of :

- **Secondary Forest (SF);**
- **Agroforestry (AF);**
- **Plantations (PL);**

R ratio of below-ground biomass to above-ground biomass for a specific vegetation type i, in ton d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to:

- **0.2** is the default for tropical moist deciduous forest when aboveground biomass is <125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for Secondary Forest, Agroforestry and non-forest.
- **3.35** is the root shoot ratio of Eucalyptus plantations according to RAZAKAMANARIVO et al. (2013). This is the case for Plantations.

Years growth Number of years to transit from Non-forest to forest. The value used is:

- **15** years is assumed as the secondary forest is assumed to have 20 years in average and the savouka jeune or non-forest represents a secondary vegetation of 5 years in average.

CF Carbon fraction of dry matter in tC per ton dry matter. The value used is:

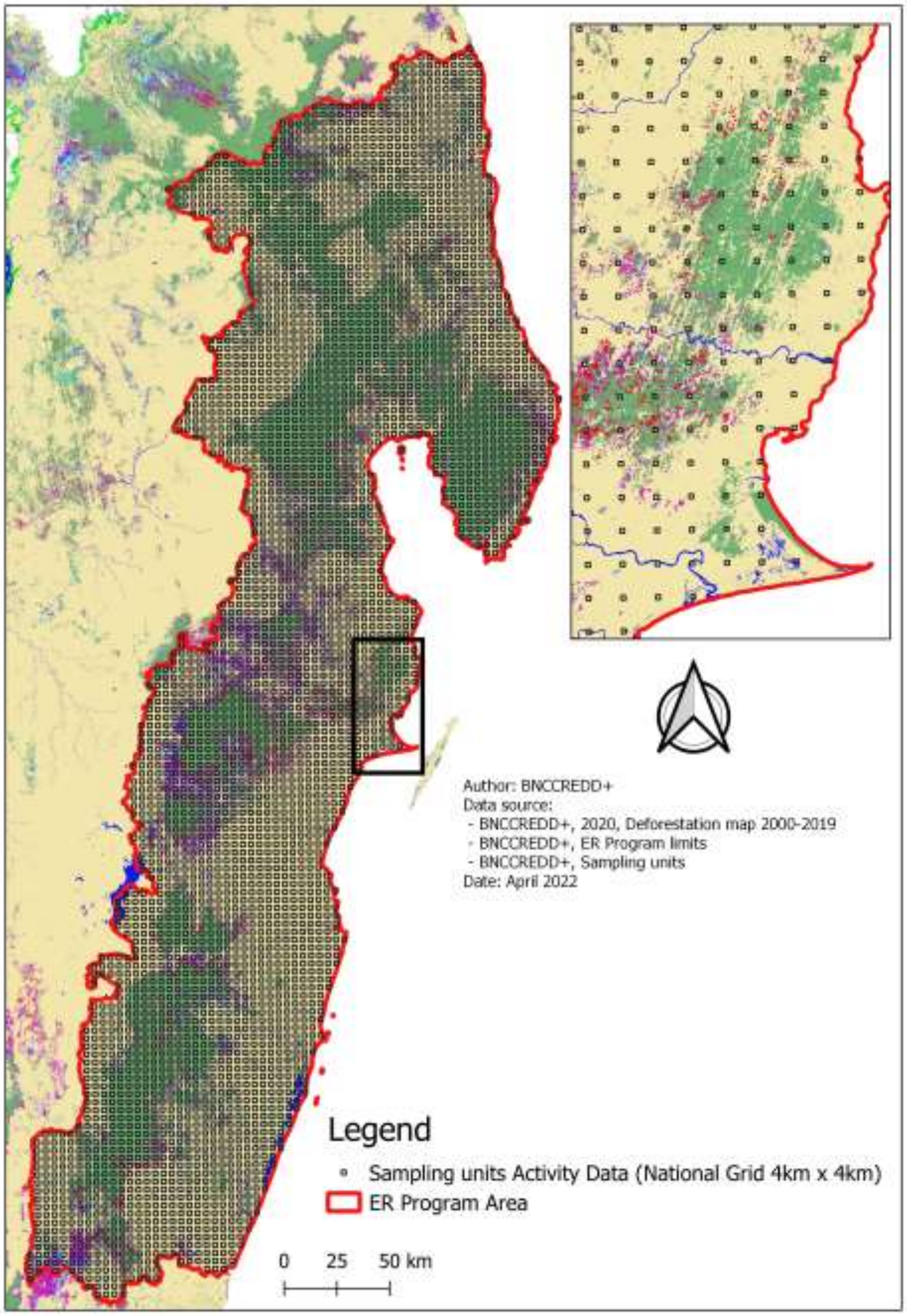
- **0.47** is the default for tropical forest as per IPCC AFOLU guidelines 2006, table 4.3.

$44/12$	Conversion of C to CO2

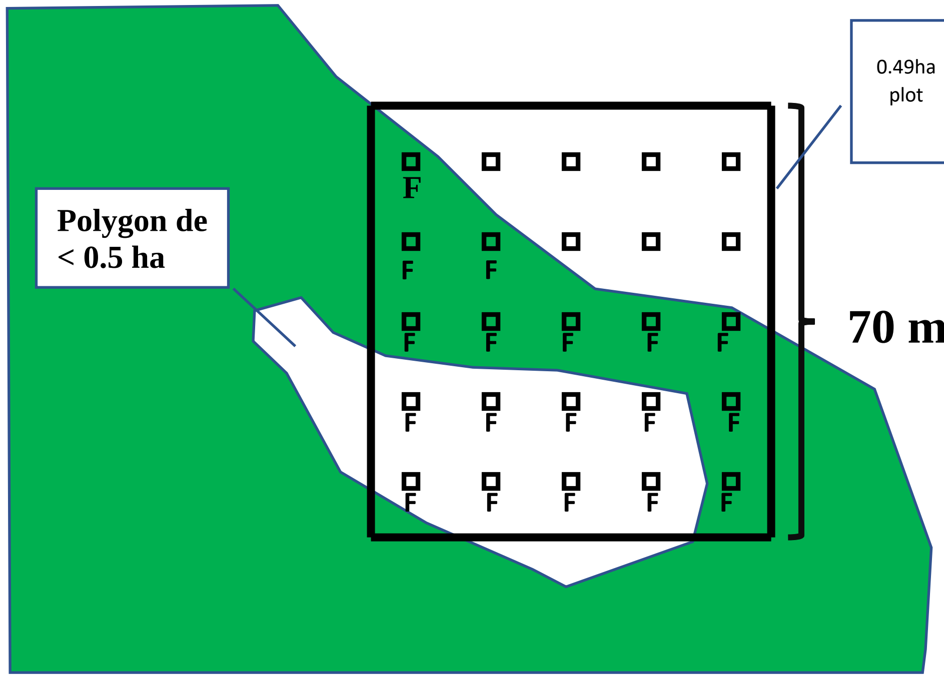
3. Data and parameters

3.1 Fixed Data and Parameters

Parameters :	$A(j,i)$ $A(i,j)$
Description :	*Annual conversion from forest type j (primary forest, modified natural forest), to non-Forest Land uses i (Non-Forest) in period 2006-2015* *Annual conversion from forest type j (primary forest), to Forest type i (modified natural forest or plantations)* *Annual conversion from non-Forest Land use i to forest type j (planted forest or modified natural forest) in period 2006-2015*
Data unit :	ha/year
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	As indicated previously, design-based inference has been used to estimate the activity data. Sampling design Estimator: Simple random estimator of a proportion Stratification: No stratification. Calculation of the sample size: No calculation since it was based on the data from the national grid. Drawing of samples Following the nationally designed grid of points for monitoring, which consist of a grid of points distant to 4km, all points contained within the limit of the program are selected. There are in total 4308 sampling points, and all of them surveyed.

	 Location of sampling units **Response design** Spatial assessment unit: The spatial assessment unit is a squared area of 70 meter of side which contains 25 points inside and which is centered on the random point selected from the sampling frame. Considering the acceptable geolocation error of Landsat imagery is 30 metres, this spatial assessment unit would be justified.

	However, in terms of spatial support the information beyond the limits of the plot were used to assess whether one object within the assessment unit would comply with the minimum mapping unit.  Assessment or sampling unit Source of the reference data: The reference data in this case will be collected through visual interpretation of all satellite imagery available to the country. This includes: ▪ Planet basemap : from 2016 to 2021, with 4.7m high resolution imagery available through the NICFI grants to tropical countries. Planet data has more recent imagery compared to other high resolution satellite images. ▪ Google Earth and Bing: All high and very high-resolution imagery accessible through Google Earth and Bing. The spatial coverage of very high-resolution imagery in the ER program area is relatively high, with many areas with coverage from 2005 to 2018. ▪ Aster: Resolution of 15 meters from 2000 to 2009 ▪ Landsat 5 TM and 7 ETM+: Available through google earth engine. ▪ Landsat 8 OLI: Available through google earth engine for 2013-2017. ▪ Sentinel 2A MSI: Available through google earth engine for 2015-2017. It is considered that these are reference data as most of the interpretations will be based on direct interpretation of higher resolution imagery for different periods which provides the necessary temporal and spatial contextual information. Reference labelling protocol ▪ Forest/Non Forest classification: In order to attribute the sample to forest class, the interpreter would evaluate how many points of the grid would fall inside a forest (a differentiated object that has at least 0,5 ha in area and has 30% of tree canopy cover). If at least 13 points (>50% of points) fall in forest, the point would be classified as forest, otherwise it is classified as non forest. This method ensures that there is no overrepresentation of forest, which happens with hierarchical classification systems. In the following example, 8 points are situated in an area of the polygon that does not have trees, this polygon is less than 0.5 hectare which is part of a bigger forested polygon with area more than 0.5ha. In this case, the sampling unit is labelled as forest class.



Example of interpretation of sampling unit

- Forest types: If the sample is classified as forest, the sample would then be attributed to one of the 5 forest types based on the majority class present:
    - Primary forest
    - Modified Natural forest – Disturbed forest
    - Modified Natural forest – Agroforestry
    - Modified Natural forest – Secondary forest
    - Plantation – Plantation for wood
- Interpretation has been based on a protocol which can be found in the website of BNCCREDD+ (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-linterpretation-des-donnees#)

Quality Control, Quality Assurance (QA/QC)

To ensure the quality of activity data, rigorous quality controls are carried out during data collection. Quality control and assurance is carried out in several layers to be robust and dependable, and that the quality of the resulting data is optimal and that the data itself contains the least possible error. The process is illustrated by the following figure:

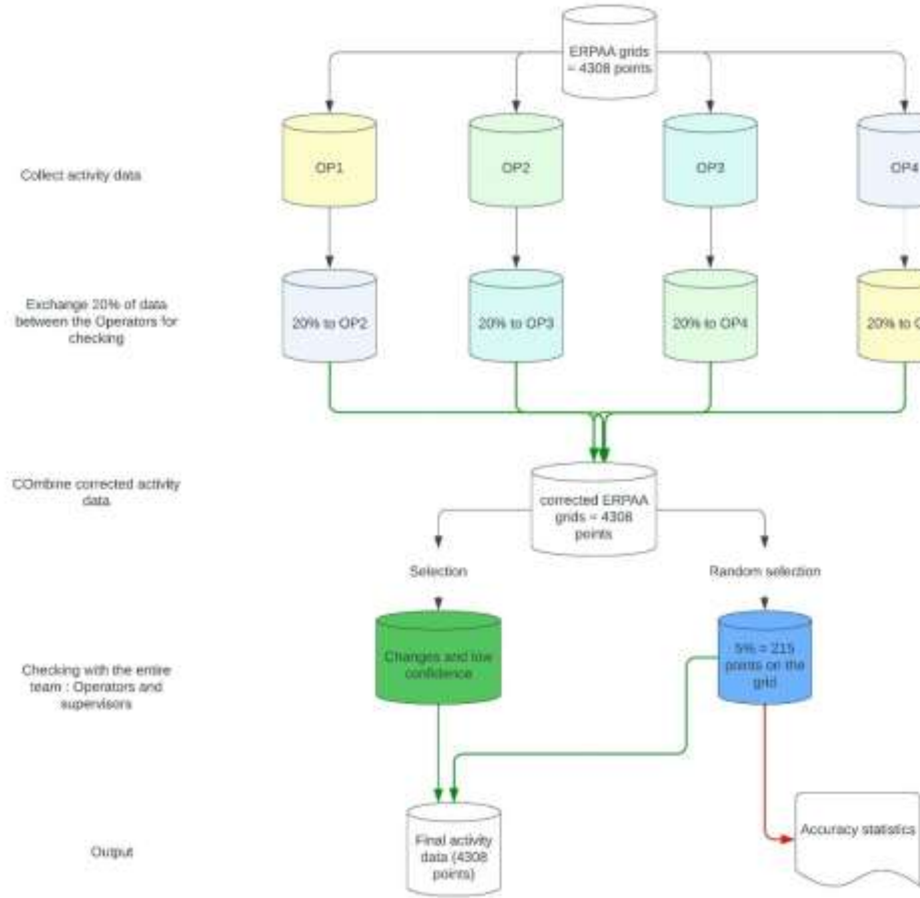


Figure 2: Activity data collection and quality control

- During data collection, operators strictly follow the data collection standard operating procedure
- In the event of ambiguity in the assignment of classes, operators seek advice from their colleagues, and if the doubt persists, mark the recording as low confidence (accuracy = NO) to be able to come back to it later with the whole team
- Once all the points have been collected, a first verification or correction is carried out: each operator checks 20% of the collections made by one of his colleagues. There are no error statistics for this first evaluation, but detected inconsistencies will be corrected immediately.
- After the 20% of exchanges, a random selection of 5% of all the data is made (215 records). Points are double-checked with the whole team: all operators and supervisors. This part evaluates the accuracy and quality of the data by comparing the data before and after verification. We could thus see the proportion of records that have undergone modifications or corrections, but in the exercise, we were more interested in records that affect emissions, so these are the land use change classes. The result of the comparison in the form of a confusion matrix is presented in Table 4. There were therefore initially 12 deforestation records, to finally, after modification and control by the entire team, there were only 10 records. Most of these modifications were the result of the modification of the dates of the changes which were initially in the window 2006-2015 but after verification, the change took place during other dates (in general after 2015).

Confusion matrix showing changes to activity data

(5% samples). C = Agriculture, F = Forest, G = Savannah, O = Bare soil, S = Artificial surface, W = Water. In red the changes in land use

		Corrected							
		CC	FF	FG	GG	OO	SS	WW	Total
Original	CC	14	0	0	0	0	0	0	14
	FF	0	77	0	0	0	0	0	77
	FG	0	1	10	1	0	0	0	12
	GG	0	0	0	105	0	0	0	105
	OO	0	0	0	0	1	0	0	1
	SS	0	0	0	0	0	2	0	2
	WW	0	0	0	0	0	0	4	4
	Total	14	78	10	106	1	2	4	215

- To understand the omissions and additions of the different classes, Table 2 summarizes the errors in percentage: 17% commission error and 0% omission error. The commission error is statistically high, but understandable and rather necessary for the rest of the processing so that we have the possibility of capturing all the changes. Note that the errors for the other classes are always very low or zero.

Evaluation of omission and commission errors based on 5% random samples

Class ID	Class	Comission error	Omission error
CC	Stable crop	0.00	0.00
FF	Stable forest	0.00	0.01
FG	**Forest loss**	**0.17**	**0.00**
GG	Stable Grassland	0.00	0.01
OO	Stable bare soil	0.00	0.00
SS	Stable Artificial	0.00	0.00
WW	Stable water	0.00	0.00

- For the evaluation of the analysts' performance, each observation is also checked against the analyst who made the data collection (Table 3). The operators were precise in the analysis and the correction rate per operator is less than 2%

Operator performance based on 5% random data

n#	Operator	Assigned points	Correct	Changed	Proportion changed
1	Baovola	49	49	0	0.00
2	Johary	67	67	0	0.00

3	Sitraka	50	49	1	0.02
4	Topaniaina	49	48	1	0.02

- Now, to have full assurance that the results are correct, 100% of the change classes (deforestation, degradation, gain) as well as the records identified with low confidence (marked accuracy = NO) are checked one by one in the presence of the whole team. This process concerns 328 observations. After verification and possible correction of possible errors on the 328 observations of classes of change and low precision, it is no longer possible to have over-evaluation of emissions, on the other hand, one could always have omissions, since one evaluates the reference level, we therefore underestimate the emissions, and our assessment would be more conservative. The number of deforestation observations before was 158, and after the verifications, we had 147 deforestation records. We note initial recordings of deforestation which are changed to stable forest (FF 16 units), and to stable savannah (GG, 8 units), these are commission errors which are therefore corrected.

Confusion matrix after final checking

C = Agriculture, F = Forest, G = Savannah, O = Bare soil, S = Artificial surface, W = Water.

		Corrected								
		CC	**FF**	**FG**	**GF**	**GG**	**OO**	**SS**	**WW**	**Total**
Original	**CC**	14	0	0	0	0	0	0	0	**14**
	FF	0	183	3	1	1	0	0	0	**188**
	FG	0	16	134	0	7	0	0	0	**157**
	GF	0	0	0	5	0	0	0	0	**5**
	GG	0	5	12	3	152	0	0	0	**172**
	OO	0	0	0	0	0	1	0	0	**1**
	SS	0	0	0	0	0	0	2	0	**2**
	WW	0	0	0	0	0	0	0	4	**4**
	Total	**14**	**204**	**149**	**9**	**160**	**1**	**2**	**4**	**543**

In terms of percentage, we had 15% commission error for deforestation and 0% commission for gain; on the other hand, there is 10% omission error for deforestation and 44% omission for gains (Table 4). It is always important to note that these errors were all corrected during quality control sessions.

Error of commission and omission for all rechecked points

(543 records in total) **Class ID**	**Class**	**Comission error**	**Omission error**
CC	Stable crop	0.00	0.00
FF	Stable forest	0.03	0.10
FG	**Forest loss**	**0.15**	**0.10**

GF	**Forest gain**	**0.00**	**0.44**
GG	Stable Grassland	0.12	0.05
OO	Stable bare soil	0.00	0.00
SS	Stable Artificial	0.00	0.00
WW	Stable water	0.00	0.00

The results of the interpretation are the following:

Analysis design
The average proportion of the variable of interest in the reference period will be estimated through the simple random estimator of the mean.

In order to convert the proportions to areas, the average proportion is multiplied by the total area of the region of interest of 6,980,308 ha.

Estimate of proportions per class

Activity	Type	Stratified estimate (proportion)	Area estimate (ha)
Deforestation	Dense humid forest	0.004	27,502
	Degraded humid foret	0.032	225,185
	Secondary forest	0.00023	1,605
	Agroforestry	0.00023	1,605
	Plantations	0.0000	0
Enhancement	Secondary forest	0.001	8,097
	Agroforestry	0.0000	0
	Plantations	0.0000	0
Degradation	PF to Disturbed forest	0.017	118,246
	PF to Agroforestry	0.0000	0
	PF to Plantations	0.0000	0
	DF to Agroforestry	0.0000	0
	DF to Plantations	0.0000	0

In order to express the proportion of deforestation or afforestation/reforestation in annual basis, the sample estimate is divided by the duration of the reference period (i.e. 10 years).

Estimate of activity data per class

Activity	Type	Area (ha/year)
Deforestation	Dense humid forest	2750.24
	Degraded humid forest	22518.47
	Secondary forest	160.55
	Agroforestry	160.55
	Plantations	0

<table>
<tr><td></td><td>
<table>
<tr><td>Degradation</td><td>PF to Disturbed forest</td><td>11824.64</td></tr>
<tr><td></td><td>PF to Agroforestry</td><td>0</td></tr>
<tr><td></td><td>PF to Plantations</td><td>0</td></tr>
<tr><td></td><td>DF to Agroforestry</td><td>0</td></tr>
<tr><td></td><td>DF to Plantations</td><td>0</td></tr>
<tr><td>Enhancement</td><td>Secondary forest</td><td>809.72</td></tr>
<tr><td></td><td>Agroforestry</td><td>0</td></tr>
<tr><td></td><td>Plantations</td><td>0</td></tr>
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More information is provided in the spreadsheet “MADA_CalculRE_v00_20211109_update_for_ER_Report_version_6” and https://drive.google.com/file/d/1QQtpS_4RpcF9rKIARd-eBE0YMeRa5H4C
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<tr><td>Value applied :</td><td>
<table>
<tr><th>Activity</th><th>Type</th><th>Area (ha/year)</th></tr>
<tr><td>Deforestation</td><td>Dense humid forest</td><td>2750.24</td></tr>
<tr><td></td><td>Degraded humid forest</td><td>22518.47</td></tr>
<tr><td></td><td>Secondary forest</td><td>160.55</td></tr>
<tr><td></td><td>Agroforestry</td><td>160.55</td></tr>
<tr><td></td><td>Plantations</td><td>0</td></tr>
<tr><td>Degradation</td><td>PF to Disturbed forest</td><td>11824.64</td></tr>
<tr><td></td><td>PF to Agroforestry</td><td>0</td></tr>
<tr><td></td><td>PF to Plantations</td><td>0</td></tr>
<tr><td></td><td>DF to Agroforestry</td><td>0</td></tr>
<tr><td></td><td>DF to Plantations</td><td>0</td></tr>
<tr><td>Enhancement</td><td>Secondary forest</td><td>809.72</td></tr>
<tr><td></td><td>Agroforestry</td><td>0</td></tr>
<tr><td></td><td>Plantations</td><td>0</td></tr>
</table>
</td></tr>
<tr><td>QA/QC procedures applied :</td><td>

QC procedures in this case consist in the establishment of a Standard Operating Procedure (SOP) for the interpretation of the samples and the capacity building and of training of each person taking part in the process in order to ensure the correct implementation of SOPs. The SOPs designed prior to the data collection may be found in the website of BNCCREDD+ (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-collecte-des-donnees#)
The forms in Collect Earth were also designed to implement validation rules that would avoid any consistency errors. Since validation rules could not avoid all possible inconsistency errors, the results of sampling units collected by an interpreter were reviewed by a different interpreter to check for inconsistencies.
Expert interpreters were used, sufficiently trained, with a specific SOP for interpretation.
Moreover, the interpreters indicate whether the quality of interpretation is high or low, so this serves to filter out those points that are of low quality in the

</td></tr>
</table>

<table>
<tr><td></td><td>interpretation. All sampling units labelled as low-confidence are re-assessed by an expert interpreter.

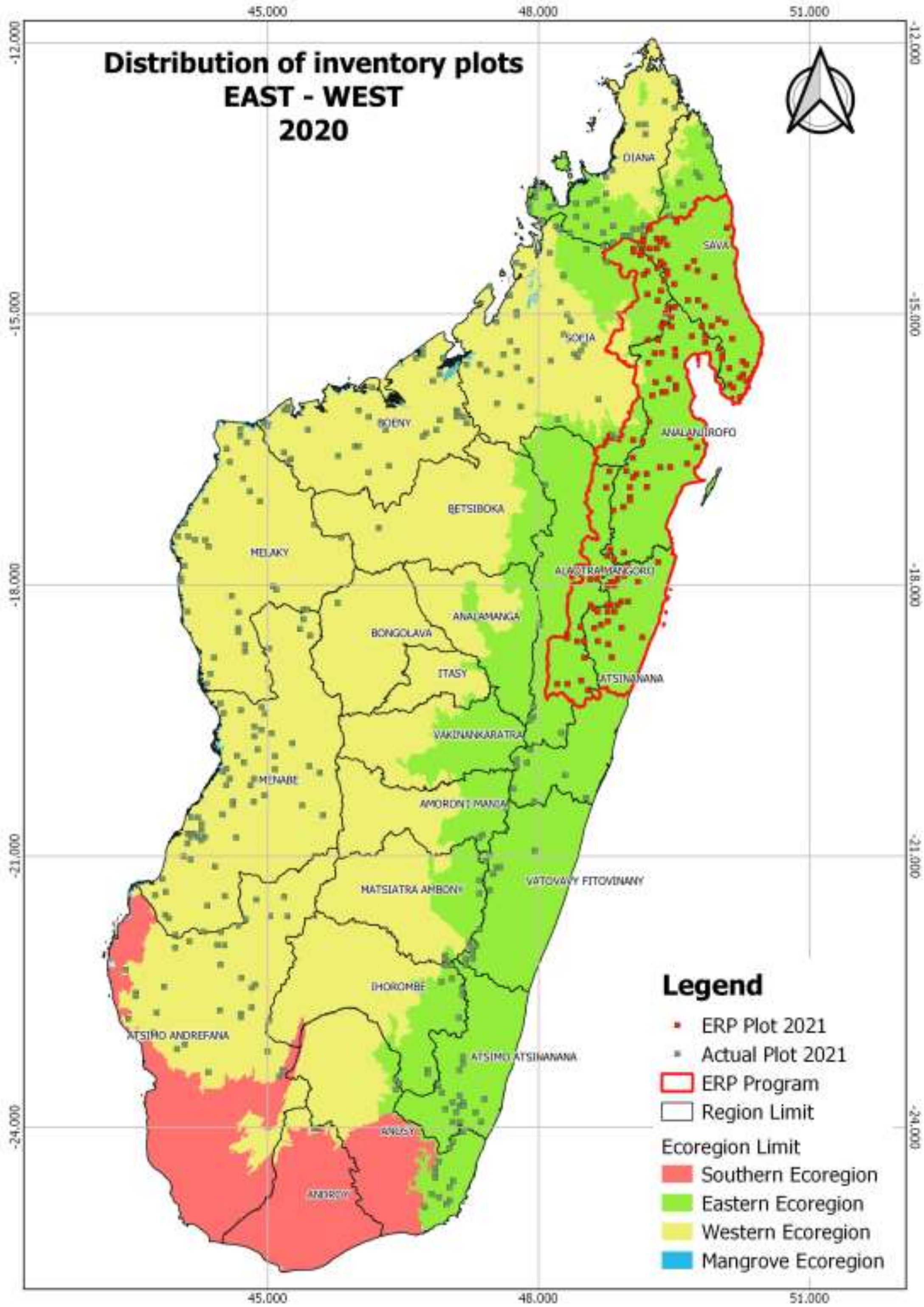
When collecting activity data in the Collect Earth tool: In general, once you fill in the information on a plot, you should do the verification of the information collected included. To see especially if the change of cover assigned and the classes of the two dates studied are logical. The result should match. An operator other than the one who performed the data collection retests a random sample of 20 percent of the total number of samples during Quality Assurance. For quality control, 5% of the total sample and all change classes and those with low confidence are reanalyzed by the group (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-collecte-des-donnees#).
During data analysis: The Laboratory and Methodology Manager, in coordination with the analysts, check that the calculations comply with SOP number 4 on data analysis, including the script used for the calculations. Then they cross-check the estimates with previously reported estimates for the same classes. Estimates are further cross-checked and compared with estimates reported by other sources (e.g. Global Forest Resources Assessment, National Greenhouse Gas Inventory, UNFCCC reports, Global Forest Watch…) (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-lanalyse-des-donnees#).
</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td>
<table>
<tr><th>Activity</th><th>Type</th><th>Standard error (proportion)</th><th>90% confidence – Relative margin of error</th></tr>
<tr><td>Deforestation</td><td>Dense humid forest</td><td>0.001</td><td>40%</td></tr>
<tr><td></td><td>Degraded humid forest</td><td>0.003</td><td>14%</td></tr>
<tr><td></td><td>Secondary forest</td><td>0.00023</td><td>165%</td></tr>
<tr><td></td><td>Agroforestry</td><td>0.00023</td><td>165%</td></tr>
<tr><td></td><td>Plantations</td><td>-</td><td></td></tr>
<tr><td>Enhancement</td><td>Secondary forest</td><td>0.001</td><td>72%</td></tr>
<tr><td></td><td>Agroforestry</td><td>-</td><td></td></tr>
<tr><td></td><td>Plantations</td><td>-</td><td></td></tr>
<tr><td>Degradation</td><td>PF to Disturbed forest</td><td>0.002</td><td>19%</td></tr>
<tr><td></td><td>PF to Agroforestry</td><td></td><td></td></tr>
<tr><td></td><td>PF to Plantations</td><td>-</td><td></td></tr>
<tr><td></td><td>DF to Agroforestry</td><td>-</td><td></td></tr>
<tr><td></td><td>DF to Plantations</td><td>-</td><td></td></tr>
</table></td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

Parameter :	$AGB_{Before,j}$ $AGB_{After,j}$ $AGB_{Before,j}$ $AGB_{After,j}$ -
Description :	Aboveground biomass of forest type j before conversion, in ton of dry matter per ha; Aboveground biomass of forest type i after conversion, in tons dry matter per ha; Aboveground biomass of forest type j before conversion, in tons of dry matter per ha; Aboveground biomass of forest type i after conversion, in tonnes dry matter per ha;
Data unit :	tdm/ha

Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	Data came from three main sources: • PERR-FH inventory, 2014: As part of the PERR-FH project, intact forests were measured in 2014 using a total of 189 plots located within the Ecoregion of the Eastern Humid Forests. • DVRF inventory, 2016: Since the national inventory did not cover secondary formations, an inventory was conducted in 2016 by DVRF targeting the following secondary forests: Agroforestry; Ravenala mixte; Ravenala; Single layer; and Savoka vieux. A total of 262 plots were measured. From all these formations, the single layer represents a more mature formation, which usually is the result of degradation of primary forest or old secondary forest. In this case, plots were located close to the forest boundary around 100-150 metres in distance. The other formations are secondary formations generally created after slash of primary forest. These formations have a similar stock of aboveground biomass, so Ravenala, Ravenala mixte and Savoka vieux has been decided to be merged into the secondary forest class. • DRGPF inventory, 2020: this inventory concerns all the forests in the eastern areas of Madagascar. This is the updating of inventory data according to the national 4kmx4km grid. 272 plots were inventoried. Three classes were considered: dense humid forest, degraded humid forest and secondary forest. *Estimates of AGB according to inventory DRGPF, 2020*

Stratum	**AGB (tdm/ha)**	**Relative margin of error at 90% of confidence level**
Dense humid forest	202.63	7%
Degraded humid forest	186.00	11%
Secondary forest	91.11	30%

Distribution of forest inventory plots

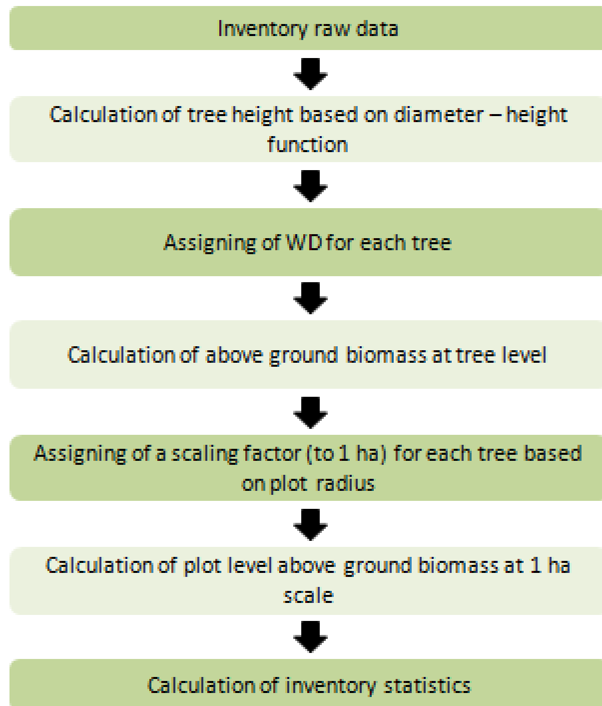


The following sections include a description on how these data were processed and the above values were derived.

A/ Processing Workflow

Inventory data was processed as follows.

Inventory data processing workflow



Inventory data used to calculate aboveground biomass was selected as follows:

- (Woody) trees of dbh ≥ 5 cm;
- All of the Palm (*Ravenala madagascariensis* and *Dypsis sp*.).

B/ Height calculation

Allometric equations used to calculate tree biomass usually have as variable the height (total height in the case of trees, total height or trunk height in the case of the palms). During the 2020 inventory, all tree heights has been measured.

A formula for calculation of heights presented was developed to be used in the future where there is no possibility to make the height measurement in the field.

The tree height measured in the field was used to develop a height-diameter relationship based on a function proposed by Chave et al. (2014). According to the field stratum, several height-diameter relations have been established. The table below shows the relations that were developed, the corresponding stratum, the number of trees used to build this relation, as well as the relative error.

For the special case of the Palm, specific relationships were also established in order to complete the data in the rare case where the height could not be measured:

- Either to measure the total height (in the case of the *Ravenala madagascariensis*), from the height of the trunk or from diameter at height of collar (DHC) depending on available data
- Or to measure the height of the trunk (in the case of the *Dypsis sp*.), from the total height.

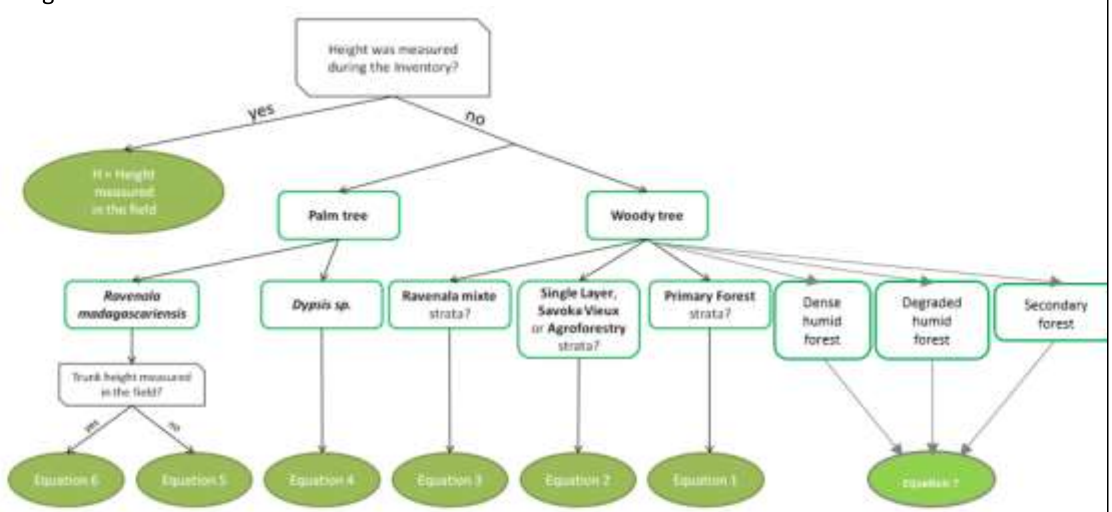
Relations used for calculating heights

Strata	N°	Equation	Number of trees	Bias /Error
Primary Forests –PERR-FH 2014 Inventory	1	$\ln(H) = -0.07511*\ln(D)^2 + 0.988*\ln(D) + 0.267$	1,270	N/A
« Savoka vieux » or « Agroforestry » strata of the 2016 inventory	2	$\ln(H) = -0.0709*\ln(D)^2 + 0.9257*\ln(D) + 0.371$	1,365	N/A
« Mix Ravenala » strata of the 2016 inventory	3	$\ln(H) = -0.106*\ln(D)^2 + 1.1305*\ln(D) + 0.0097$	499	N/A
Palm: Dypsis sp.	4	$H_{stip} = 0.3772*H + 1.7639$	25	N/A
Palm: Ravenala madagascariensis	5	$\ln(H) = -0.0699*\ln(DHC)^2 + 0.9956*\ln(DHC) – 0.8902$	1,010	N/A
	6	$H = 0.9391*H_{stip} + 5.7537$	493.	N/A
Humide Forest DRGPF 2020 Inventory	7	$H = 0,0362 (D)2 + 1,0742 D + 4,86$	18,959	N/A
Humid forest (Chave et al. 2014)		$H = 1.389026 \times \exp(0.980517 \times \ln(D))*\exp(-0.07032031 \times (\ln(D))^2)$	2519	16%
Humid forest (Vieilledent et al 2012)		$Ln(H) = 1.010+0.547 * \ln(D)+Error$	250	+4.7 meter

Where:
H: total height, in m
D: diameter at breast height, in cm
DHC: diameter at collar height (Palm trees) in cm
H_{stip}: height of the trunk (Palm trees), in m

Later in the calculations, this calculated height by tree has been used only for trees which were not measured in height on the ground: in other cases, it is the measured height that was used.

The choice of the relation to be used to calculate the height is illustrated by the decision tree shown in Figure below.



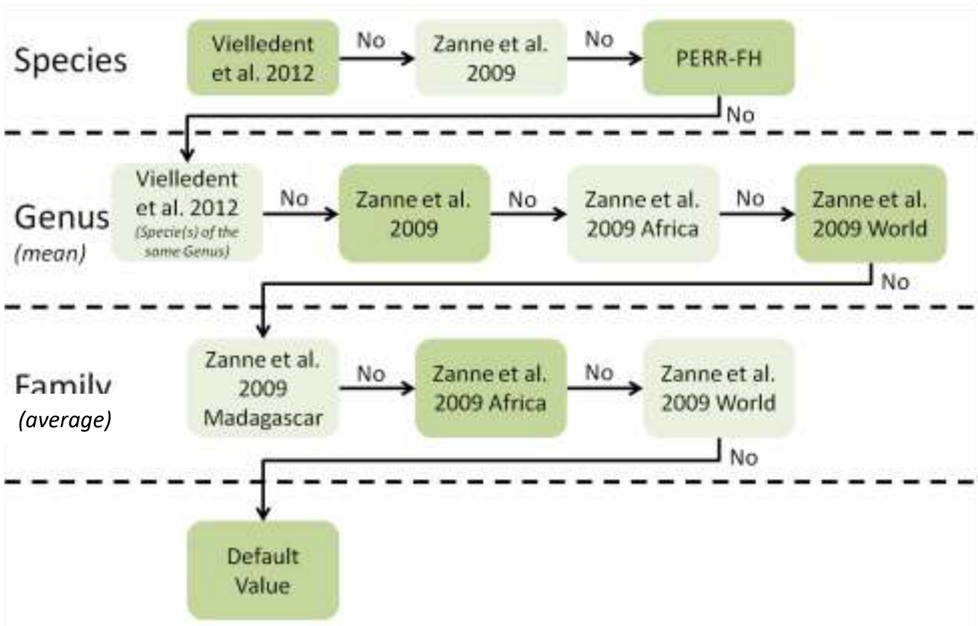
Decision tree to calculate height

Official Use

C/ Wood density assignation

For the assessment of site/species biomass, the search for species, genus and family level densities was paramount. For this, the databases of Vielledent et al (2012), Zane et al (2009), Zane et al (2009) Madagascar, Perr-FH and LRA (2021) were used.

The figure below was followed when searching for specific densities.



Decision tree for assigning WD

Wood densities were assigned based on the following 3 main databases:

1. A wood density database compiled by Vielliedent et al. (2012) for research related to allometric equations
2. The global wood density database compiled by Zanne et al. 2009
3. The PERR-FH wood density database compiled by the PERR-FH project for the purpose of the PERR-FH inventory

In the order of the above appearance, these 3 databases were searched for a WD value at the species level. If no WD value was found or only the genus of the tree was known, then WD values were assigned based on the genus in the following order of priority:

1. WD value from a species of the same genus from the database of Vieilledent et al. (2012)
2. Mean WD across the genus for species found in Madagascar from the database of Zanne et al. 2009
3. Mean WD across the genus for species found in Africa from the database of Zanne et al. 2009
4. Mean WD across the genus from the entire database of Zanne et al. 2009

In cases where only a single species of the same genus was found, the WD of this species was assigned.

If no WD value was available at the genus level or only the family of the tree was known, then WD values were assigned based on the family in the following priority order:

1. Mean WD across the family for species found in Madagascar from the database of Zanne et al. 2009
2. Mean WD across the family for species found in Africa from the database of Zanne et al. 2009
3. Mean WD across the family from the entire database of Zanne et al. 2009

Finally, if no wood density could be assigned through the above process either because no WD data was unavailable or the tree could not be identified then a conservative WD default value of 0.5 was assigned (this value was chosen because it corresponds to the default value used in the PERR-FH project).

D/ Calculation of AGB at tree level

The tree level biomass was calculated based on the following allometric equation.

Allometric equations used to calculate ground biomass

STRATA OR SPECIES		EQUATION	SOURCE
Trees (woody)	Humid forests (DRGPF 2020, inventory)	$\ln(AGB_{est}) = -1.103+1.994*LN(D)+0.317*LN(H_{tot})+1.303*LN(\rho))$	Vieilledent et al. (2012)
	Primary forests (PERR-FH 2014 inventory), modified forests ('Old Savoka' or 'Agroforestry' strata of the 2016 Inventory)	$\ln(AGB_{est}) = -1.948+1.969*LN(D)+0.66*LN(H_{tot})+0.828*LN(\rho))$	Vieilledent et al. (2012)
	(woody) trees of modified forests (« Ravenala mixte » strata of the inventory)	$\ln(AGB_{est}) = -1.56 + 1.912*\ln(D) + 0.471*\ln(H_{tot}) + 0.732*\ln(\rho)$	Ramananantoandro et al., 2015
Palms	*Ravenala madagascariensis*	$\ln(AGB_{est}) = -5.08 + 5.654*\ln(H_{tot}) - 0.772*\ln(H_{tot})^2$	Ramananantoandro et al., 2019

	Dypsis sp.	By default, the allometric equation that has been used is that of the *Chrysophylla sp* species as this was the equation which gave better results: $AGB_{est} = 0.182 + 0.498 * H_{stip} + 0.049 * H_{stip}^2$ Olofsson et al. (2014)	IPCC 2003 LULUCF GPG, Annex 4A.2 (Delaney et al. 1998 ; Brown et al. 1999)

With:

AGB_{est}: Estimated *Above-Ground Biomass* in tdm

ρ: Wood density

D: Diameter at Breast Height (DBH), in m

H_{tot}: Total height of the tree or palm (for the palm, including fronds)

H_{stip}: Height of the trunk (stem height of the Palm, without considering the fronds)

E/ Calculation of AGB at plot level

A scaling factor was applied to scale the values calculated at the individual tree level to 1ha. Since each plot consists of 04 subplots, different scaling factors were assigned based on the DBH of each tree. Table 5 shows the scaling factors for the fixed-size subplots.

Plots description

DBH [cm]	**Sides**	**Surface (Side*Side) in m²**	**Scaling factor**	**DBH [cm] Ecoregion**	
				Est	Ouest
Small trees	10	100	100	5 <DBH≤15	5< DBH ≤10
Medium trees	20	400	25	15< DBH ≤30	10< DBH≤20
Large trees	50	2,500	4	>=30	>=20
Regenerations	(1*1)*4	4	2500	<5	<5

DBH (cm), total height (m), dead tree quality were recorded.

F/ Inference

**** Arithmetic mean***

Sampling does not give real values. The results of the sampling are always estimates of the total population studied. Therefore, the average was calculated using the following formula.

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

(13)

Where y_i is the parameter value for the i^{th} sample and n is the total number of samples collected. Arithmetique mean computation was automated in an Excel worksheet.

The average was used to estimate the average value of total height, bole height and diameter at breast height at 1.30m from the ground. The analysis of the value of land area, volume and biomass was also done by calculating the arithmetic mean. Finally, it was used to know the general trend of the standing trees or the formation in general in the areas of inventories.

Estimates of above-ground biomass per forest type

Forest type	**AGB (tdm/ha)**	**Number of samples**
Dense humid forest	202.63	155
Degraded humid forest	186.00	85
Secondary forest	91.11	21

More information is provided in the spreadsheet ¨ MADA_Biomasse_aerienne_et_Morte_20220410_v01 ¨ which may be found in the link https://drive.google.com/file/d/1Bgm0DqFAFN7zIeeOrGHhYgDaUIycvMa1

Value applied:

Forest type	**Estimate (tdm/ha)**
Dense Humid forest	202.63
Degraded humid forest	186.00
Secondary Forest	91.11
Agroforestry	87,87
Plantation	29,55

QA/QC procedures applied:

During data collection, a team of supervisor spot checked 5% of the plots (DRGPF, 2021). The team went in the field and randomly chose surveyed plot, demanded the team to remeasure everything while the quality control team observe to see if they follow the SOP and parameters are measured correctly and data are recorded in the correct format that permit infallible retrieving later.

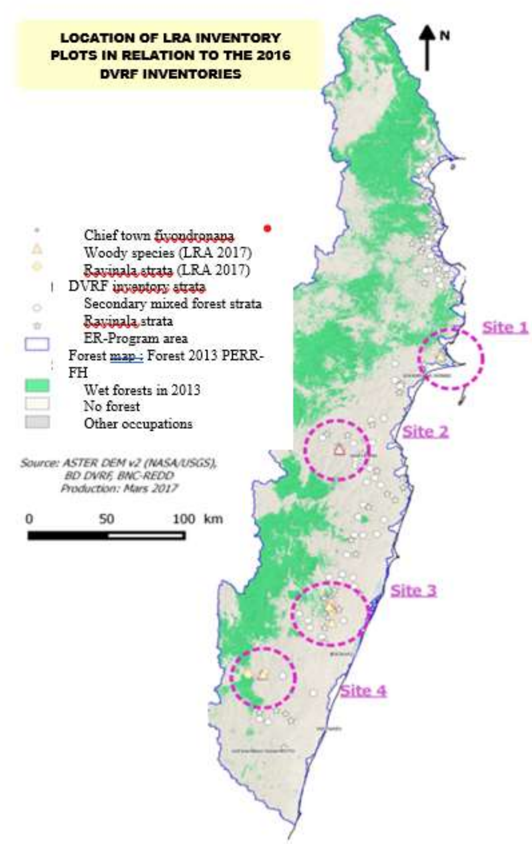
Data processing were checked regularly and at every step by the Methodology unit at BNCCR with team of experts working with them.

Uncertainty associated

Class	**BA (tdm/ha)**	**Stdev**	**Number of samples**	**SE**	**Relative margin of error at 90%**

with this parameter:	Dense Humid forest	202.63	99.59	155	8.00	7%
	Degraded humid forest	186.00	111.90	85	12.14	11%
	Secondary Forest	91.11	72.79	21	15.88	30%
	Agroforestry	87.87	40.45	28	7.64	15%
	Plantation	29.55			6.25	35%
Any comment:						

Parameter:	$AGB_{After,i}$ $AGB_{Before,i}$ *(non-forest)*
Description :	Aboveground biomass of non-forest type j before conversion, in tonne of dry matter per ha Aboveground biomass of non-forest type i after conversion, in tonnes dry matter per ha;
Data unit:	tdm/ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international) :	This are sourced from a destructive sampling of Savoka Jeune secondary formations conducted as part of the Laboratoire de Recherches Appliqués in 2016-2017. These formations are the precursors of Savoka vieux, Ravenala mix and agroforestry formations. ***A/ Sampling design*** The samples were located in four different areas, located in the Centre and the South of the ER program area. These locations are part of the regions of Analanjirofo, Atsinanana and Alaotra Mangoro. Its general characteristics are the following: • Site 1 (Axe Soanierana Ivongo): centre of the ER program and below 200 m of altitude; • Site 2 (Axe Vavatenina): centre of the ER program and at least 400 m of altitude; ; • Site 3 (Axe Brickaville): south of the. ER program and below 400 m of altitude; • Site 4 (Axe Andasibe): south of the ER program and above 400 m of altitude.



Location of plots for estimation of biomass in non-forest

In each of the sites several 1 m^2 plot were established and they were established at different locations within watersheds in order to understand the impact of this in the aboveground biomass. Moreover, the plots within each of the slopes were located on Savoka jeune with different ages ranging from 4 to 10 years in order to understand the variability of Savoka Jeune with age. A total of 292 plots were established.

Number of sampling units per site for the estimation of biomass in Savouka Jeune

Topographic position	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**TOTAL**
C1 : low slope	19	27	21	22	292
C2 : mid-slope	23	26	24	24	
C3 : high slope	19	34	27	26	
TOTAL per site	61	87	72	72	292

B/ Measurement

Within these plots, a destructive measurement of herbaceous vegetation and woody vegetation was made. The samples were then taken to laboratory and the samples were dried at a

	temperature of 70°C for the leaves and the herbaceous vegetation and 103°C for the shrubs until constant weight between 24-hour intervals. In general, the drying process has taken 3 days in the case of leaves and grasses, and the woody biomass has taken 5 days.  *Picture of bags with destructive samples* The anhydrous mass of the shrubs and grasses has been measured with a balance with 0.01 g accuracy. ***C/ Statistical analysis*** Different statistical parameters was evaluated: The average estimate of Aboveground Biomass is estimated through the random estimator of the mean ($\hat{\mu}$): $$\hat{\mu} = \frac{1}{n}\sum_{k=1}^{n} y_k$$ Where: • y_k is the k sample estimate given by the biomass estimated per plot as described above. This is the biomass per sampling unit estimated above. • n is the number of samples • For the all four sites, the biomass factor for Savoka jeunes is of 11.96 ±6.5 t/ha.
Value applied:	11.96
QA/QC procedures applied:	Inventory quality control: technical supervision by DRGPF and BNCCREDD+ supervisors and strategic supervision by MEDD staff, verification of inventory sheets and databases.
Uncertainty associated with this parameter:	The main uncertainty is the sampling uncertainty and the representativeness of the data. See Chapter 12. The sampling error is estimated through the following formula. $$\widehat{Standard\ error}(\hat{\mu}) = \frac{1}{\sqrt{n} \times (n-1)} \times \sum_{k=1}^{n} (y_k - \hat{\mu})^2$$ Where:

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- y_k is the k sample estimate given by the biomass estimated per plot as described above. This is the biomass per sampling unit estimated above ;
- $\hat{\mu}$ the random estimator of the mean;
- n is the number of samples.

The result is multiplied by the t-student value for the 90% confidence level in order to estimate the confidence interval. The margin of error is the half width of the confidence interval divided by the average estimate.

Estimates of AGB in non-forest

Class	AGB (tdm/ha)	Stdev	Number of samples	SE	Relative margin of error at 90%
Non Forest	11.96		120	3.28	46%

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<tr><td>Any comment:</td><td></td></tr>
</table>

Parameter:	C_O
Description :	dead wood/litter stock, under the old land-use category, tons C ha-1.
Data unit:	tC/ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The same calculation procedures as the aboveground biomass were followed, but only with the trees that were labelled in the field as dead trees. This resulted in the following: *Estimates of dead wood per forest type* **Forest type** / **DW (tdm/ha)** Dense humid forest / 0.08 Degraded humid forest / 0.09 Secondary forest / 0.06 These values were then multiplied by 0.47 in order to provide the carbon stocks.
Value applied:	**Forest type** / **Value** Dense humid forest / 0.08 Degraded humid forest / 0.09 Secondary forest / 0.06
QA/QC procedures applied:	Inventory quality control: technical supervision by DRGPF and BNCCREDD+ supervisors and strategic supervision by MEDD staff, verification of inventory sheets and databases.

<table>
<tr><td>Uncertainty associated with this parameter:</td><td>
<table>
<tr><th>Class</th><th>DW (tdm/ha)</th><th>SE</th><th>Relative margin of error at 90%</th></tr>
<tr><td>Dense humid forest</td><td>0.08</td><td>0.01</td><td>19%</td></tr>
<tr><td>Degraded humid forest</td><td>0.09</td><td>0.01</td><td>21%</td></tr>
<tr><td>Secondary forest</td><td>0.06</td><td>0.02</td><td>67%</td></tr>
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<tr><td>Any comment:</td><td></td></tr>
</table>

<table>
<tr><td>Parameter:</td><td>$SOC_{Before,j}$ $SOC_{After,i}$</td></tr>
<tr><td>Description :</td><td>Soil Organic Carbon at 30 cm depth of forest type j before conversion, in tonne of carbon per ha and Soil Organic Carbon at 30 cm depth of non-forest type j after conversion, in tonne of carbon per ha.

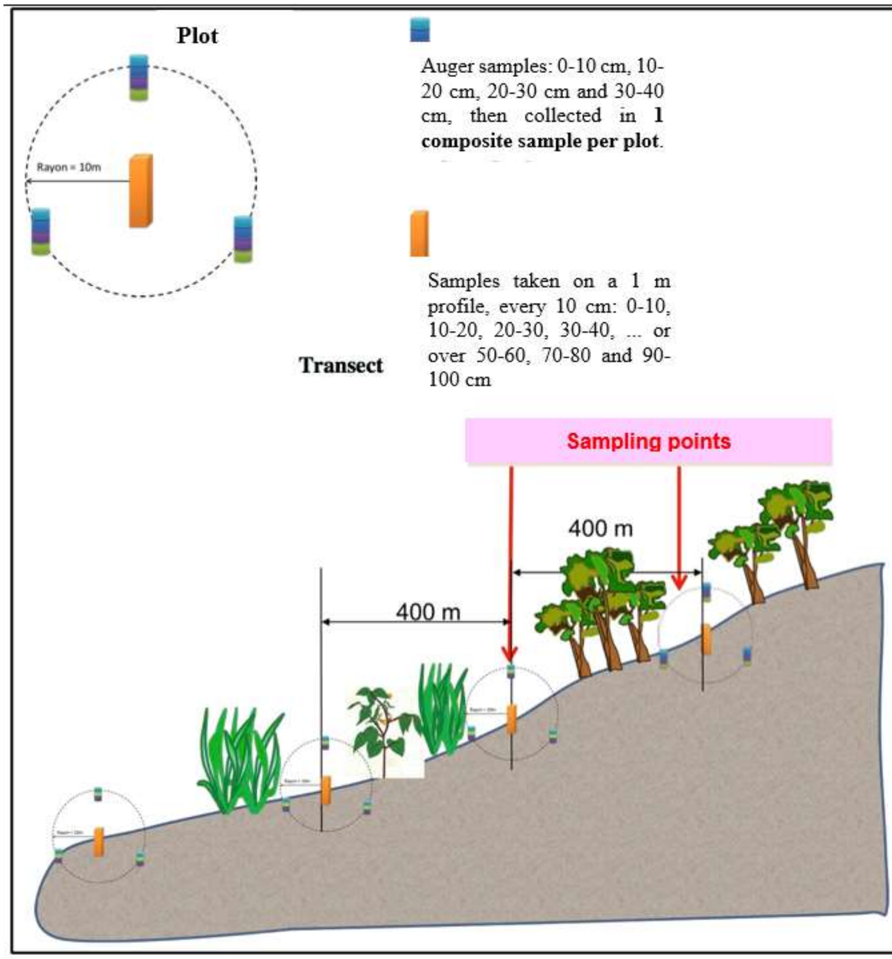
SOC_{Before} corresponds to SOC of the forest and SOC_{After} corresponds to SOC of non forest</td></tr>
<tr><td>Data unit:</td><td>tC/ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):</td><td>The data of soil estimates are based on a specific inventory conducted in the Eastern Humid Ecoregion as part of the PERR-FH (https://redd.unfccc.int/files/20180528_frel_mada_modified.pdf)

A/ Sampling plan
The inventory consistent in sampling in four different regions within the ecoregion, where 5 different chrono sequences were established.


</td></tr>
</table>

	Location of soil sampling units

The chronosequences was established to understand the changes in carbon stocks from Forests to the Tavy system, and to understand these changes across time as shown in the following figure.



View of the chrono sequences sampling for soil organic carbon

A total of 200 samples were collected, 75 in forest and 125 in non-forests, 50 in each of the four regions identified.

Sample size for the estimation of SOC

Class	Forest	Non-Forest	Total
Ambanja	26	24	50
Tamatave Est	22	28	50
Moramanga Sud	11	39	50
Ivohibe	16	34	50

Total	75	125	200

B/ Measurement H

Data was collected following best practice standards in soil measurement. This was done for the profile down to 30 cm of depth and 1 meter of depth. Once collected the samples, apparent density and carbon content are estimated.

The most commonly used method for calculating soil organic carbon stocks at equivalent volume is to measure C stocks for each layer and taking into account apparent density and coarse content (EG: stoniness) of the soil. . The calculation of carbon stock in mega grams of C per hectare (Mg C / ha, or tonne of C per hectare t C / ha) is done using the equation presented below:

$$SOC_i = DA \times 0{,}1 \times (1 - (EG/100)) \times C_{org} \times e$$

Where:

SOCi : Carbon stocks in depth i (i = 0-10 cm, 10-20 cm, 20-30 cm), en tC/ha;

DA : Aparent density, en g/cm3 ;

EG : Percentage of gross elements > 2 mm, in %;

Corg : Organic carbon content, en g C/kg ;

e : Depth of the horizon, in cm (ici e = 10 cm).

The SCO for depths of 0 to 30 cm (SCO_30) were obtained by summing the stocks calculated for each thickness (0-10cm, 10-20cm, 20-30cm) (PERR-FH. 2015)). The corrections necessary to take into account the presence of coarse elements have been applied; thus, the mineral fraction greater than 2 mm (EG), being supposed to be devoid of C was thus removed from the stock. In this sense, for the first 30 cm of soil, the volume equivalent stock is calculated with the following equation:

$$SCO\_30 = SCO_{0\text{-}10} + SCO_{10\text{-}20} + SCO_{20\text{-}30}$$

The link to the document showing this equation is : https://drive.google.com/file/d/1r5a7zylbp0XJala0dY4MJT0Lhxv0URT_

Les stocks de C à volume équivalent ont été principalement utilisés pour la cartographie et la modélisation du carbone du sol.

C/ Inference

The soil organic carbon stocks are estimated and provided in the following table

Estimates of SOC for forest and non-forest according to PERR-FH

Class	**SOC (tdm/ha)**	**N**	**Standard deviation**
Forest	110.97	125	39.17
Non-Forest	104.65	75	37.53

<table>
<tr><td></td><td>These estimates were then assigned to all classes including primary forest and modified natural forest.</td></tr>
<tr><td>Value applied:</td><td>

Class	**Value**
Primary Forest (PF)	110.97
Modified Natural Forest – Disturbed Forest (DF)	110.97
Modified Natural Forest – Secondary forest (SF)	110.97
Modified Natural Forest – Agroforestry (DF)	110.97
Plantations – plantations for wood	0
Non-Forest	104.65

</td></tr>
<tr><td>QA/QC procedures applied:</td><td></td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td>The sampling error is provided below.
Estimates of SOC for forest and non-forest according to PERR-FH

Class	**90% level – confidence interval**
Forest	5%
Non-Forest	7%

</td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

3.2 Monitored Data and parameters

<table>
<tr><td>Parameter :</td><td>$A(j,i)$ $A(i,j)$</td></tr>
<tr><td>Description :</td><td>• Annual conversion from forest type j (primary forest, modified natural forest), to non-Forest Land uses i (Non-Forest) in the monitoring period
• Annual conversion from forest type j (primary forest), to forest type i (modified natural forest and plantations) in the monitoring period
• Annual conversion from non-Forest Land use i to forest type j (planted forest or modified natural forest) in the monitoring period</td></tr>
<tr><td>Data unit :</td><td>ha/year</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>

Activity	**Type**	**Area (ha/year)**
Deforestation	Dense humid forest	678
	Degraded humid forest	16,553.71
	Secondary forest	0
	Agroforestry	0
	Plantations	0
Degradation	PF to Disturbed forest	19,888.22
	PF to Agroforestry	0
	PF to Plantations	0
	DF to Agroforestry	0

</td></tr>
</table>

	DF to Plantations	0
Enhancement	Secondary forest	0
	Agroforestry	0
	Plantations	0

Source of data and description of measurement/calculation methods and procedures applied:

Sampling design: Due to the project area size, and the very small proportion of change (deforestation and gain), a stratified random estimates was chosen to the most appropriate sampling method.

Estimator:

Stratified random estimator of a proportion

Stratification:

A forest cover change map was created as stratification criteria. The initial target stratum was stable forest, stable non forest, forest loss, forest gain and a buffer around areas prone to errors (deforestation, gain, forest edges). Upon running the process, there were no gain identified so that was removed from the land use class, Also, errors can beminimised by post-stratifying the buffer into two depths : buffer from 50m from forest edge and a second buffer from 50m to 100m from forest edge. Water was part of the land use classification but not included in the stratum since no sampling points will be set in the water. More information on the methods for production of the maps is provided in SOP0 (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-stratification#).

Table 6 : Stratification used for the activity data estimation

Strata
11-Forest
12-Deforestation
22-Non-forest
55- Buffer Forest 50 m-100 m
56- Buffer Forest 0-50 m

Precision and confidence level:

Relative margin of error of 20% at 90% of confidence level as requested

Calculation of the sample size:

For the calculation of the sample size, the equation from Cochran (1977, Eq. (5.25)) was used assuming that the cost of sampling each stratum is the same:

$$n = \frac{(\sum W_h S_h)^2}{[S(\hat{O})]^2 + (1/N)\sum W_h S_h^2} \approx \left(\frac{\sum W_h S_h}{S(\hat{O})}\right)^2$$

Where:

W_h Weight of stratum *i*;

S_h Standard deviation of variable of interest in stratum i;

$S(\hat{O})$ Standard error of the variable of interest.

N Number of sampling units in the region of interest (i.e., population size);

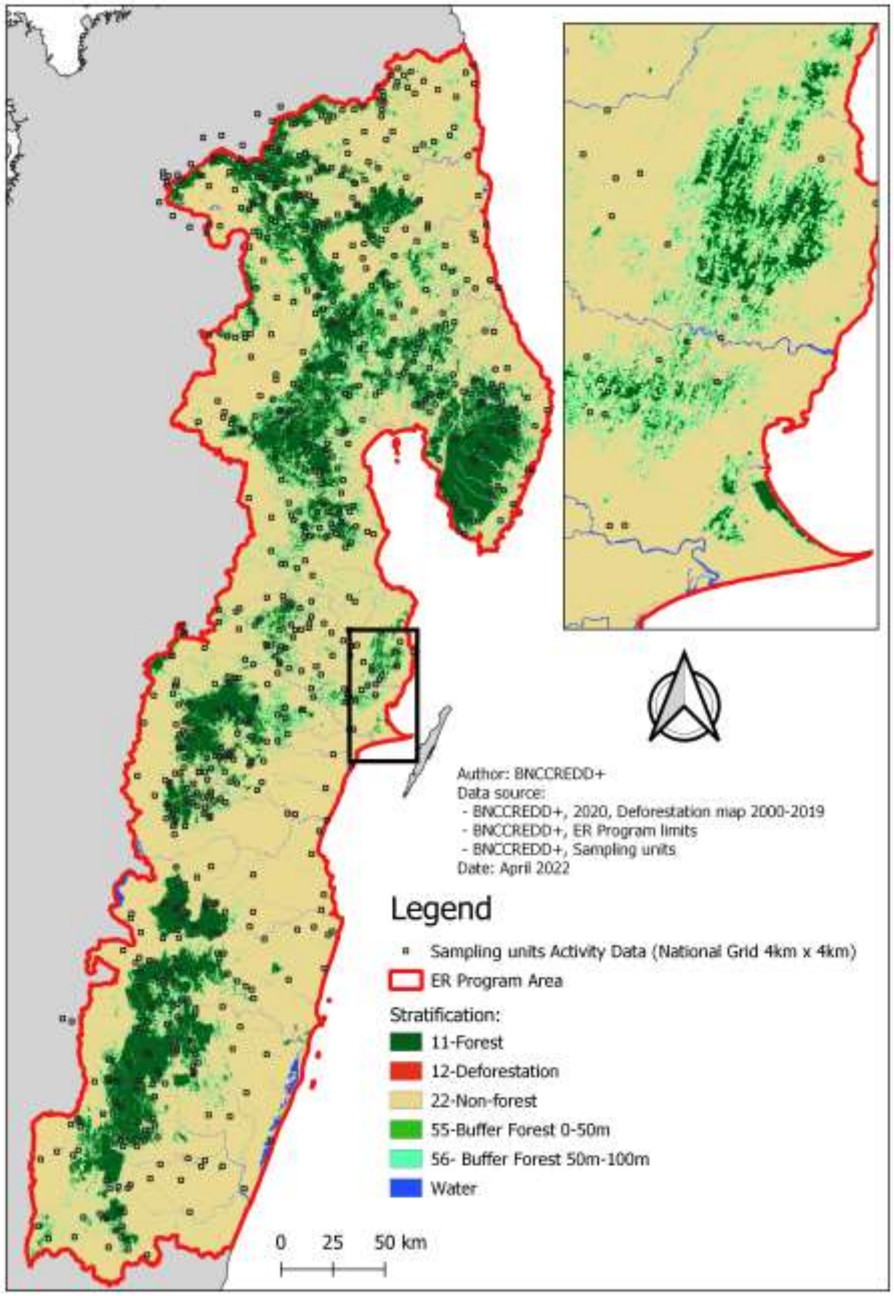
The sample size was estimated through an iterative approach and using proportion of total deforestation as the variable of interest:

- First of all, 100 sampling units were collected per stratum.

	- A calculation of the sample size was done, and as a result 300 additional samples were added in all strata. - A new calculation of the sample size was done and resulted in 250 additional samples added to each stratum. Sample allocation was based on a proportional approach as shown in the below table.

Calculation of number of samples per stratum

Code	**Class**	**Weight of strata**	**Number of samples**
11	Stable Forest	0.1771	300
12	Deforestation	0.0036	150
22	Stable Non Forest	0.6886	150
55	Buffer Forest 50m-100m	0.0637	272
56	Buffer Forest0m-50m	0.0669	1,074



Location of sampling units and stratification

Response design

Spatial assessment unit:

The spatial assessment unit is a squared area of 70 meter of side which contains 25 points inside and which is centered on the random point selected from the sampling frame. Considering the acceptable geolocation error of Landsat imagery is 30 meters, this spatial assessment unit would be justified.

However, in terms of spatial support the information beyond the limits of the plot were used to assess whether one object within the assessment unit would comply with the minimum mapping unit.

Assessment or sampling unit

The same sampling unit (square of 70 m x 70 m) was used for the data collection.

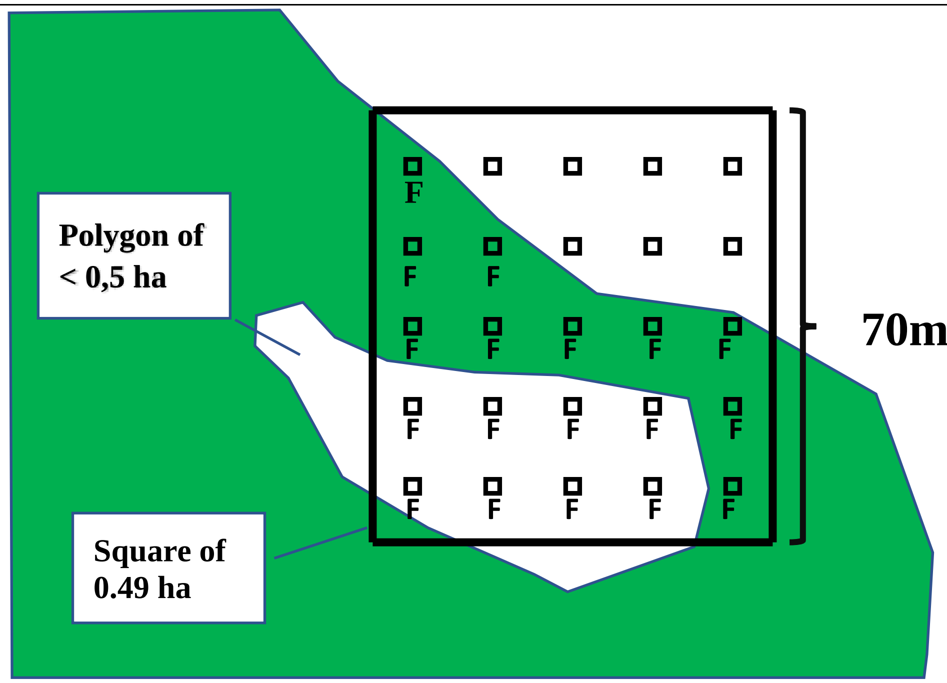
Data collection by interpreters:
Interpreters assess sample units, using the interpretation key as a guide to assess different land use classes and transitions. The interpreters consult each other and the Laboratory Manager if they have any doubts about the interpretation of the image.
The Laboratory Manager organizes a validation based on a set of samples evaluated by two or more interpreters.
During data collection, the Laboratory Manager encourages discussions and a group evaluation of the samples with all the interpreters for mutual validation and good calibration with a common understanding of the techniques by the group.
The Laboratory Manager notes challenges and limitations during data collection as well as potential sources of bias during data collection.

Data assembly:
Once data collection is complete, the Laboratory Manager compiles a data set which should include the following information:
• A database of sample data collected by interpreters including:
o Geographic coordinates defined in the coordinate or projection system
o The unique identification code for each sample unit o The interpretation of all sample units, including the previous interpretation(s) of the sample unit in case this has been revised or corrected.

- QA/QC: A number of QA/QC procedures have been applied:

Quality Assurance/Quality Control (QA/QC):
The interpreters reanalyze the individually collected data (taking a random percentage of samples (in our case, 20%)) by inverting the collection results. The results are then, if

	necessary, reanalyzed as a group during a series of sessions during which all samples with changes are reanalyzed. Samples with doubt are also closely reviewed. All of these samples must constitute 5 percent of the number of sample units. *Source of data:* The data in this case was collected through visual interpretation of all satellite imagery available to the country. This includes : ▪ Planet basemap: from 2016 to 2021, with 3m high resolution imagery available through the NICFI grants to tropical countries. Planet data has more recent imagery compared to other high resolution satellite images. ▪ Google Earth and Bing: All high and very high-resolution imagery accessible through Google Earth and Bing. The spatial coverage of very high-resolution imagery in the ER program area is relatively high, with many areas with coverage from 2005 to 2015. ▪ Aster: Resolution of 15 meters from 2000 to 2009 ▪ Landsat 5 TM and 7 ETM+: Available through google earth engine. ▪ Landsat 8 OLI: Available through google earth engine for 2013-2017. ▪ Sentinel 2A MSI: Available through google earth engine for 2015-2017. It is considered that these are reference data as most of the interpretations will be based on direct interpretation of higher resolution imagery for different periods which provides the necessary temporal contextual information. *Reference labelling protocol* ▪ Forest/Non-Forest classification: In order to attribute the condition of forest to the sample, the interpreter evaluated how many points of the grid would fall over forest (a differentiated object that has at least one ha in area and has 30% of tree canopy cover). If at least 13 points (>50% of points) fall in forest, the point would be classified as forest, otherwise as non-forest. This method ensures that there is not a overrepresentation of forest, which happens with hierarchical classification systems. In the example below, although only 10 points fall over canopy, 18 points fall in forest area, so the sampling unit is classified as forest.



Example of interpretation of sampling unit

- Forest types: If the sample is classified as forest, the sample would then by attributed to one of the 5 forest types based on the majority class present:
  - Primary forest
  - Modified Natural forest – Disturbed forest
  - Modified Natural forest – Agroforestry
  - Modified Natural forest – Secondary forest
  - Plantation – Plantation for wood
- Interpretation has been based on a protocol found in this link (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-linterpretation-des-donnees#)

The results of the interpretation are the following:
Sampling units per strata

		Strata			
Activity	**Type**	**1**	**5**	**10**	**9**
Deforestation	Primary forest	1	14	0	0
	Disturbed forest	5	42	0	1
	Secondary forest	0	0	0	0
	Agroforestry	0	0	0	0
	Plantations	0	0	0	0
Enhancement	Secondary forest	2	2	0	0
	Agroforestry	0	0	0	0
	Plantations	0	0	0	0
Degradation	PF to Disturbed forest	54	29	3	0

	PF to Agroforestry	0	0	0	0
	PF to Plantations	0	0	0	0
	DF to Agroforestry	0	0	0	0
	DF to Plantations	0	0	0	0
Total number of samping units		677	677	699	422

Verifications with ancillary data:
If external data exists, the Laboratory manager uses these external data sources (eg maps, etc.) to make a comparison with the classification of the sampling unit. Discrepancies between the two sets of data can be reported by the Laboratory Manager. Confirmed differences between the two datasets can be documented to show why sample-based area estimation may yield different results compared to other data sources.

Performance evaluation
By having the .csv data of the activity data and the stratification map in raster version, or the .csv table of the proportion of each stratum with the surfaces in number of pixels and in hectares, as well as the number of samples per stratum, a matrix of proportions is established. Analysts construct a matrix that shows strata (map classes) and reference classes. The matrix lists the numbers of sampling units and areas of the stratification map.

An error matrix is obtained which is recorded. Analysts then calculate stratum weights by dividing the area of each class or stratum by the total reporting area. We obtain a table on the area and the weight of the strata using an R script and we must retrieve the file area_stratum.csv, and calculate the weight of the stratum.

Analysis design
The average proportion of the variable of interest in the reference period will be estimated through the stratified random estimator of the mean ($\hat{\mu}_{STR}$)

$$\hat{\mu}_{STR} = \sum_{h}^{H} W_h \hat{\mu}_h$$

Where:
W_h Weight of stratum *h*;
$\hat{\mu}_h$ Sample estimates within stratum *h* which is equal to $\hat{\mu}_h = \frac{1}{n_h}\sum_{k=1}^{n_h} y_{hk}$ where y_{hk} is the *i*th sample observation in the *h*th stratum
In order to convert the proportions to areas, the average proportion is multiplied by the total area of the region of interest of 6,980,308 ha.

Estimate of proportions per class

Official Use

Activity	Type	Stratified estimate (proportion)	Area estimate (ha)
Deforestation	Dense humid forest	0.00009	678
	Degraded humid forest	0.0023	16,554
	Secondary forest	0.0000	0
	Agroforestry	0.0000	0
	Plantations	0.0000	0
Enhancement	Secondary forest	0.0000	0
	Agroforestry	0.0000	0
	Plantations	0.0000	0
Degradation	PF to Disturbed forest	0.003	19,888
	PF to Agroforestry	0.0000	0
	PF to Plantations	0.0000	0
	DF to Agroforestry	0.0000	0
	DF to Plantations	0.0000	0

The proportion of deforestation or afforestation/reforestation is expressed in an annual basis.

Estimate of activity data per class

Activity	Type	Area (ha/year)
Deforestation	Dense humid forest	678
	Degraded humid forest	16,553.71
	Secondary forest	0
	Agroforestry	0
	Plantations	0
Degradation	PF to Disturbed forest	19,888.22
	PF to Agroforestry	0
	PF to Plantations	0
	DF to Agroforestry	0
	DF to Plantations	0
Enhancement	Secondary forest	0
	Agroforestry	0
	Plantations	0

More information is provided in the spreadsheet "MADA_CalculRE_v00_20211109_update_for_ER_Report_version_6" and https://drive.google.com/file/d/1QQtpS_4RpcF9rKIARd-eBE0YMeRa5H4C

<table>
<tr><td>QA/QC procedures applied:</td><td>QC procedures in this case consist in the establishment of a Standard Operating Procedure (SOP) for the interpretation of the samples and the application of training procedures in order to ensure the correct implementation of SOPs (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-linterpretation-des-donnees# , https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-collecte-des-donnees#)

The labeling or assignment of a class to a sample is checked three times:
- A first time, by the analyst or interpreter who interprets the satellite images for the year or study period and on the basis of different sources (Landsat, Sentinel, Google Earth, etc.);
- During QA/QC: for quality assurance, a random 20 percent of the samples is checked by another analyst (exchanges of results files) who is taken at random according to the organization set by the Laboratory Manager; rectification is made in the event of an error of interpretation;
- During QA/QC: for quality control, samples with low confidence, samples with changes (deforestation, degradation and forest gain) are re-analyzed by the team concerned who form a discussion and validation committee for the output of the final result. The overall total retested should be at least 5 percent of the total number of samples. Rectification is made in the event of an error of interpretation. It is also important to pay attention to the following point during the interpretation: The distinction between deforestation and forest remaining burnt forest must imperatively be made by exploiting all the sources of information available from the archives of satellite images because it proves that a forest remaining forest that is burned, is not necessarily a land use conversion.</td></tr>
<tr><td>Uncertainty for this parameter:</td><td>
<table>
<tr><th>Activity</th><th>Type</th><th>Standard error (proportion)</th><th>90% confidence – Relative margin of error</th></tr>
<tr><td rowspan="5">Deforestation</td><td>Dense humid forest</td><td>0.00004</td><td>81%</td></tr>
<tr><td>Degraded humid forest</td><td>0.0002</td><td>17%</td></tr>
<tr><td>Secondary forest</td><td>-</td><td></td></tr>
<tr><td>Agroforestry</td><td>-</td><td></td></tr>
<tr><td>Plantations</td><td>-</td><td></td></tr>
<tr><td rowspan="3">Enhancement</td><td>Secondary forest</td><td>-</td><td></td></tr>
<tr><td>Agroforestry</td><td>-</td><td></td></tr>
<tr><td>Plantations</td><td>-</td><td></td></tr>
<tr><td rowspan="5">Degradation</td><td>PF to Disturbed forest</td><td>0.001</td><td>51%</td></tr>
<tr><td>PF to Agroforestry</td><td></td><td></td></tr>
<tr><td>PF to Plantations</td><td>-</td><td></td></tr>
<tr><td>DF to Agroforestry</td><td>-</td><td></td></tr>
<tr><td>DF to Plantations</td><td>-</td><td></td></tr>
</table>
</td></tr>
<tr><td>Any comment :</td><td></td></tr>
</table>

4. Quantification of emission reductions

4.1 ER Program Reference level for the Monitoring/Reporting Period covered in this report

Table 7: ER Program Reference level for the Monitoring/Reporting Period

Year of Monitoring/Reporting period *t*	Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr	If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical removals by sinks over the Reference Period (tCO_{2-e}/yr)	Adjustment, if applicable (tCO_{2-e}/yr)	Reference level (tCO_{2-e}/yr)
2020	11,442,849	420,060	-13,254		11 849 654
2021	11,442,849	420,060	-26,508		11 836 401
2022	11,442,849	420,060	-39,762		11 823 147
2023	11,442,849	420,060	-53,016		11 809 893
2024	11,442,849	420,060	-66,270		11 796 639

4.2 Estimation of emissions by sources and removals by sinks included in the ER Program's scope

Process summary

Activity	Steps	Explanation
Sampling design (LOFM)	Establishment of stratum	Map of land use and change used for the stratification (SOP 0) Calculation of stratum weight W_h $W_h = \frac{Area\ of\ stratum}{Total\ area}$
	Identification of number of samples	Use the formula from Cochran, 1977 $n = \left(\sum_{h=1}^{H} \frac{W_h S_h}{SE}\right)^2 = \frac{t^2}{E^2} \times \left(\sum_{h=1}^{H} W_h S_h\right)^2$ Where - n is the number of samples - W_h the weight of stratum - S_h the standard error
Activity data collection (LOFM)	Setting up collect earth forms and templates	SOP1 response design
	Definition of UOT (land use and change classes)	
	Collecting AD in Collect earth	SOP1 data collection/response design

Data analysis (LOFM)	Quantity of Forest becoming non-Forest (deforestation)	SOP2 data analysis Step 1 : frequency of deforestation Step 2 : evaluation of area of deforestation Step 3 : evaluation of uncertainties
	Quantity of degradation: Primary Forest becoming secondary forest	Step 1 : frequency of the estimator Step 2 : area of the estimator Step 3 : uncertainties
	Estimation of Emission reduction	Step 1 : evaluation of the frequency of gain Step 2 : evaluation of quantity of gain Step 4 |: uncertainties
	Estimation of emission due to fire	Step 1 : evaluation of frequency of fire Step 2 : evaluation of area affected by fire Step 3 : uncertainties
Identification of Emission reduction	Emission factor determination	Step 1 : 459 plots in the humid forest has been surveyed to evaluate the biomass expansion factor and determine the biomass per hectare of forest in the project area Step 2 : Biomass has been converted to Carbon stock
	Emission	Emission for the crediting period is the total of emissions (deforestation, degradation, fire) minus the gain
	Emission reduction or removals (ER)	The Emission Reduction is the difference between the baseline emission compared to the Emission from crediting period
Uncertainties and sensitivity analysis	Monte Carlo simulation	Monte Carlo simulation of all parameters using 10.000 simulation (provided in the mada_uncertainty_analysis_v02.xlsx)

Calculation

Emission and removals are computed by first calculating areas of loss and gains, applying the Emission factor to the areas to obtain respectively biomass and carbon stock, and deduct the Emission and Removals.

For the loss/emission, we are calculating:

- Deforestation which is defined as the transition from forest to non-forest land use. In this category, there is Primary Forest to non-forest land, secondary forest to non-forest land, and plantation to non-forest land.
- Degradation is the defined as a transition of forest land use into a lower/more degraded land use without leaving the forest definition threshold.

For the gain, we are calculating:

- Gain of forest which is the transition from non-forest land to forest land (non-forest to secondary forest)
- Gain in plantation which is the transition from non-forest land to forest land (non-forest to plantation)

The emission due to fire is calculated by looking at presence of fire as reason of degradation or deforestation (this is identified by looking at the cause of deforestation or degradation and noting if it is due to fire)

The formula to calculate each parameter are the same and we provide here the example of deforestation. Also, all the calculation are made automatic by using R scripts so only the principles are presented here by using the deforestation as an example.

Evaluation of amount of deforestation

The area of deforestation can be calculated by multiplying the total area of the area of interest (sampling frame) Aby the stratified estimator of the proportion of the variable i which is deforestation ($\hat{p}_{DEF}$). One could use other statistical estimators, but the common practice now are stratified estimators.

This value is the proportion of the region of interest classified as deforestation.

$$\widehat{A_{DEF}} = \mathrm{A} \times \hat{p}_{DEF}$$

To calculate the stratified estimator ($\hat{p}_{DEF}$), we multiply the weight of each stratum h (W_h) by the proportion of each stratum h ($\overline{p_{h,i}}$)

$$\hat{p}_{DEF} = \sum_{h}^{H} W_h \overline{p_{h,DEF}}$$

The weight is calculated based on the map, the proportion is calculated based on the samples.

Estimate of the confidence interval of the area of deforestation

The absolute error at 90% confidence is equivalent to half the confidence interval (Half Width of the Confidence Interval). We calculate the absolute error with the following equation:

$$Error_{90\%} = t_{student} \cdot \sqrt{\widehat{Var}(p_{DEF})}$$

Where, t $t_{student}$ is the t- student at 90% confidence level (aprox . 1.67) and $\sqrt{\widehat{Var}(p_{DEF})}$is the standard error or typical deviation of the sample mean.$\widehat{Var}(p_{DEF})$ is the variance of the mean, which in this case is the stratified estimator presented above.

The variance is calculated with the following equation, where Wi is the weight of each stratum, ni is the number of samples in each stratum, and $\hat{\sigma}_i^2$is the sampling variance.

$$\widehat{Var}(p_{DEF}) = \sum_{h=1}^{H} W_h^2 \times \mathrm{Var}(\overline{p_{h,DEF}})$$

This variance is calculated with the following equation:

$$\hat{\sigma}_h^2 = \mathrm{Var}(\overline{p_{h,DEF}}) = \frac{p_{h,DEF}(1 - p_{h,DEF})}{n_h - 1}$$

Sample calculation of Emission Reduction

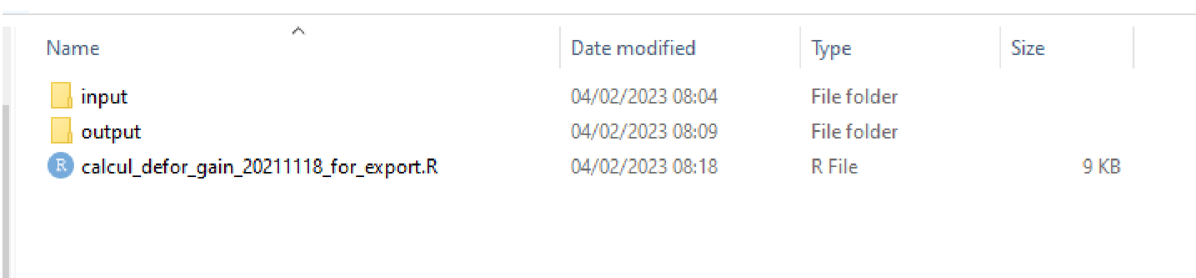
In this sample, step by step calculation is shown in processing of the activity data to the generation of the Emissions and Removals. The steps here are already provided in SOP4 Data analysis.

Inputs :

Activity data table (results from collect earth) as data_with_stratum_20210928.csv
Area and weight of each stratum used in the sampling area_stratum.csv
Area of ERPAA (calculated from the table above)
R script used to process that data calcul_defor_gain_20211118_for_export.R
Excel spreadsheet MADA_CalculRE_v00_20211109_update_for_ER_Report_version_6.xlsx

Steps

The script is designed to read input data from a folder input, and write results in folder output. The folder structure is then arranged so that the R script can find the input and output folder, and should then be arranged as in the picture below:



Now, open the script in R-Studio and change the working directory according to where the file is in the computer. Normally, this is the only change to be made on the script and it, but if the activity data have a different name, also change the change the filename.

After the script runs, there will be a few .csv table in the output folder, each of the file corresponds to activity and parameters used to compute the Emissions and removals and values from these files are input into the excel spreadsheet for that purpose.

sample > output

Name	Date modified	Type	Size
defor_stat_lu.csv	04/02/2023 08:39	Microsoft Excel C...	4 KB
degradation.csv	04/02/2023 08:39	Microsoft Excel C...	1 KB
degradation_total.csv	04/02/2023 08:39	Microsoft Excel C...	1 KB
feux_only.csv	04/02/2023 08:39	Microsoft Excel C...	1 KB
gain_stat_lu.csv	04/02/2023 08:39	Microsoft Excel C...	1 KB

Defor_stat_lu.csv is the file with the information on deforestation activity. In that file, we are interested in any rows with lu_level2 with the value "FG", these corresponds to change from Forest to Grassland, or any other non-forest land use. In this example, deforestation occurred in two (02) land use types : FHI (Humid intact forest) and FHD (Degraded Humid Forest). Statistics from each are going to be created manually.

	lu_level2	lu_level3	fq_abs	fq_rel	variance	std_error	uncertain	area	CI	stratum	wh
1	FF		297	0.99	1.03E-06	0.001017	0.001691	1223553	2068.672	11	0.177057
2	FF	FHI	1	0.003333	3.47E-07	0.000589	0.290886	4119.707	1198.363	11	0.177057
3	GG		2	0.006667	6.92E-07	0.000832	0.205343	8239.414	1691.905	11	0.177057
4	FF		33	0.22	1.52E-08	0.000123	0.000922	5593.564	5.154712	12	0.003642
5	FF	FHI	3	0.02	1.73E-09	4.16E-05	0.003426	508.5058	1.742103	12	0.003642
6	FG	FHD	72	0.48	2.21E-08	0.000149	0.000509	12204.14	6.216817	12	0.003642
7	FG	FHI	4	0.026667	2.30E-09	4.79E-05	0.002957	678.0077	2.004753	12	0.003642
8	GG		29	0.193333	1.38E-08	0.000117	0.001	4915.556	4.914125	12	0.003642
9	GG	SSar	1	0.006667	5.86E-10	2.42E-05	0.005974	169.5019	1.012623	12	0.003642
10	GG	SSararb	5	0.033333	2.85E-09	5.34E-05	0.002636	847.5097	2.233693	12	0.003642
11	GG	SZararb	3	0.02	1.73E-09	4.16E-05	0.003426	508.5058	1.742103	12	0.003642
12	FF		5	0.033333	0.000102	0.010093	0.498288	160231	79841.2	22	0.688641
13	GG		144	0.96	0.000121	0.011018	0.018888	4614652	87159.54	22	0.688641
14	WW		1	0.006667	2.09E-05	0.004576	1.12947	32046.19	36195.22	22	0.688641
15	FF		258	0.948529	7.29E-07	0.000854	0.001481	421998.5	625.1732	55	0.063736
16	FF	FHI	8	0.029412	4.26E-07	0.000653	0.036534	13085.23	478.0501	55	0.063736
17	GG		6	0.022059	3.22E-07	0.000568	0.042345	9813.919	415.5688	55	0.063736
18	FF		825	0.768156	7.43E-07	0.000862	0.001846	358839.8	662.4935	56	0.066923
19	FF	FHI	5	0.004655	1.93E-08	0.000139	0.049137	2174.787	106.8634	56	0.066923
20	FG	FHD	10	0.009311	3.85E-08	0.000196	0.034664	4349.573	150.7738	56	0.066923
21	GG		232	0.216015	7.06E-07	0.00084	0.006402	100910.1	646.0335	56	0.066923
22	GG	SZararb	1	0.000931	3.88E-09	6.23E-05	0.11008	434.9573	47.88008	56	0.066923
23	WW		1	0.000931	3.88E-09	6.23E-05	0.11008	434.9573	47.88008	56	0.066923

We know that for estimates from stratified random sampling is as follow :

$$Pi\ (Estimate) = \sum_{i}^{n} ((\text{Relative frequency of stratum})\text{x}\ (\text{Weight of the stratum}))$$

$$Variance = \sum Variance\ per\ stratum$$

$$Standard\ error = \sqrt{Variance}$$

Estimate FHD = 0.48*0.003642 + 0.009311*066923 = 0.002371487
Variance FHD = 0.00000002208 + 0.00000003847 = 0.00000006054
Standard error FHD = SQRT(0.00000006054) = 0.000246055

The same calculation is used to calculate the Estimate for FHI,
Estimate FHI = 0.000097131490
Standard error = 0.00004791383

Degradation.csv contains the same information as above but related to the degradation. The same exact calculation apply, in our case, there is only one land use type affected by degradation so the number can be read directly from the table without any more computation
Estimate FHI = 0.002849
Standard error FHI = 0.000891

Feux_only.csv contains the information about activity data that was due to burning. It contains the same information and calculation of the parameters are the same as the other.
Estimate FHD = 0.000128
Standard error FHD = 0.000086143

Gain_stat_lu.csv contains the gain (regeneration, reforestation), with all the statistics like the above, and calculation of the estimate is the same. Only for this case, there are no records of gain, so all parameters are just zero (0).

Emissions and removals
These are the information necessary information needed for the estimation of Activity data, the next step is to plug each number into the appropriate cells in the excel spreadsheet MADA_CalculRE_v00_20211109_update_for_ER_Report_version_6.xlsx. In the tab "DA" (short for données d'activité, French for Activity Data), the monitoring section start at row 32. After each parameter are input (Stratified estimate and standard error), activity data for each category is automatically computed, and the emission reduction updated in the tab "Reduction d'émissions".

USE OF PARAMETERS (ACTIVITY DATA AND EMISSION FACTORS) FOR THE CALCULATION OF FREL AND EMISSION MONITORING :

-Calculation of the FREL (cf MADA Calcul RE file, Niveau de Référence sheet)
*Identification of reference periods
The reference period must be identified first. This period lasts 10 years and is the period before the start of the project or before the monitoring period. The case of the ERPAA here is therefore 2006 to 2015.
*Definition of REDD+ activities considered (deforestation, degradation, enhancement, etc)
The REDD+ activities considered need to be well defined : are the calculating emissions from deforestation or degradation or both ? Is enhancement or reforestation also considered for the calculation of removals ?
If so, the calculations described by REDD+ activities are performed in the MADA Calcul RE excel file, Niveau de Reference sheet.
*Preparation of ADs (data collection, processing of results by script, production of results)
Here, we begin by collecting the data needed to calculate the FREL. In this case, the national grid is used to sample the points to be collected according to the zones to be considered or zones already delimited. The objective is to know the change of land use of these samples during two different periods. Here, we use different images to collect in this case high resolution images such as Google Earth, landsat, sentinel, planet, etc…
These samples have specific sizes according to the definition of forests at the country level. The case here, square 70m*70m because the minimum area according to the new definition of forests in Madagascar is 0,50ha. Once the sample sizes are defined, we proceed to the actual data collection using the software collect earth.
At the end of the collection, we obtain information of the csv points identified by sample. This csv file can be changed to excel.
This consolidated csv file of all zones will be used in the script software to output statistics by REDD+ activity and by stratum or land use type (area, absolute frequency, relative frequency, variance, standard error, uncertainty, confidence interval, etc…) (see matrix example, statistical results from script processing, deforestation activity, below)

N°	alu_2006_sub	freq_abs	freq_rel	variance	std_error	uncertainty	Area	ci
1	AF	1	0.0002321	5.38701e-08	0.000232099	1.64501653	1605.10329	2640.421
2	FHD	139	0.0322655	7.24802e-06	0.002692215	0.13727497	223109.3581	30627.331
3	FHI	17	0.00394614	9.12389e-07	0.000955190	0.39823335	27286.7560	10866.496
4	FSS	1	0.000232126	5.38701e-08	0.000232099	1.64501653	1605.1032	2640.421

* Update of data by REDD+ activities on stratified estimates or estimates, standard errors through statistical results of the ADs (in the file MADA Calcul RE, DA sheet, entitled Niveau de Référence)
Once the matrices from the scripts or statistical results are output, they can be used in the DA sheet by filling the estimate and standard error lines with freq_rel and std_error
*Update of biomass data according to the latest inventories (Excel table, Biomasse sheet)
The values of biomass, Stdev, Sample number, SE, Relative error, etc have been updated according to the results of the last forest inventory (here, it is the 2020 inventory).
Note that the formula of Veilledent et al (2012) was used for the calculation of aboveground biomass. Indeed, the development of this formula involved data from the forests of eastern Madagascar. Also, the local values obtained from local measurements are the most recommended and approximate the realities. The formula is :

$$AGB = EXP(-1.103 + 1.994 * Ln(DBH) + 0.317 * Ln\ (H) + 1.303 * Ln\ (\rho)$$

with :

AGB : Above ground biomass, expressed in tons of dry matter (tdm)

ρ : infra density of wood (t/m^3)

DBH : Diameter at Breast Height (DBH) (cm)

H : Total height of the tree (m)

*Calculation of the FREL itself (Excel table, Niveau de référence sheet)
The calculations of emissions or removals by REDD+ activities are done automatically according to the formulas, and the value of the FREL appears automatically at the bottom (see table whose title is highlighted in green) by following the formula :
FREL= Deforestation Emission + Degradation Emission -Absorption
Thus, we obtain the average emissions during the reference period, and the FREL value appears in the first row of the column « Total annual historical GHG emissions », here it is the value 11,849,654 tCO2/year.
It should be noted that the calculation of emissions per REDD+ activity follows the formula :
Emission (tCO2/year) = Activity Data (AD) x Emission Factors (EF)
AD: Land use change area: Example: deforestation area, obtained through data collection with the collect earth software, expressed in ha/year
EF: It is the amount of CO2 emitted when clearing 1 ha of forest, expressed in tCO2/ha and follows the following formula:
$\boldsymbol{EFj}$ = (Biomass Before,$\boldsymbol{j}$ – Biomass After,$\boldsymbol{j}$) $\boldsymbol{x\ CF\ X}$ 44/12
With
$\boldsymbol{EFj}$: Emission factor for transition j in tons CO2 ha-1.
Biomass Before,$\boldsymbol{j}$: Biomass stock before conversion from forest to non-forest stage, for transition j, in tons of dry matter ha-1

Biomass After,j : Biomass stock after conversion from forest to non-forest stage, for transition j, in tons of dry matter ha-1. In the case of dead biomass, the in accordance with the IPCC recommendations for Level 1, the value was considered to be zero.
CF : Fraction of carbon in dry biomass.
44/12 : Carbon expansion factor at CO2.

-<u>Calculation of emissions for the monitoring period</u>
*<u>Identification of monitoring periods</u>
First, identify the years of emissions tracking. Here, it is the year 2020
*<u>Definition of REDD+ activities considered (deforestation, degradation, enhancement, etc)</u>
The REDD+ activities considered need to be well defined : are the calculating emissions from deforestation or degradation or both ? Is enhancement or reforestation also considered for the calculation of removals ?
If so, the calculations described by REDD+ activities are performed in the MADA Calcul RE excel file, Suivi sheet.
*<u>Preparation of the AD (data collection, development of the stratification map, confusion matrix, production of results)</u>
We start with the delimitation of the considered areas. We then proceed to the downloading of images (date 1 and date 2) for the stratification map. We work on the classification of images with ROI. Then, we proceed to the sampling of the points to collect. Define the sample sizes according to the definition of forests and finally the collection of data itself using the software collect earth and using different images (Google earth, landsat, sentinel, etc).
At the end of the collection, we obtain information of the csv points identified by sample. The csv file can be changed to excel.
This consolidated csv file of all zones will be used in the script software to output statistics by REDD+ activity and by stratum or land use type (area, absolute frequency, relative frequency, variance, standard error, uncertainty, confidence interval, etc…) (see matrix from example, statistical results from script processing, deforestation activity (FG, Forest to Grassland), below)

N°	lu_lev2	lu_lev3	fq_abs	fq_rel	variance	std_error	uncertainty	area	CI	stratum	wh
1	FF		297	0,99	1,03E-06	0,001017	0,001691	1223553	2068,672	11	0,177057
2	FF	FHI	1	0,003333	3,47E-07	0,000589	0,290886	4119,707	1198,363	11	0,177057
3	GG		2	0,006667	6,92E-07	0,000832	0,205343	8239,414	1691,905	11	0,177057
4	FF		33	0,22	1,52E-08	0,000123	0,000922	5593,564	5,154712	12	0,003642
5	FF	FHI	3	0,02	1,73E-09	4,16E-05	0,003426	508,5058	1,742103	12	0,003642
6	FG	FHD	72	0,48	2,21E-08	0,000149	0,000509	12204,14	6,216817	12	0,003642
7	FG	FHI	4	0,026667	2,30E-09	4,79E-05	0,002957	678,0077	2,004753	12	0,003642
8	GG		29	0,193333	1,38E-08	0,000117	0,001	4915,556	4,914125	12	0,003642
9	GG	SSar	1	0,006667	5,86E-10	2,42E-05	0,005974	169,5019	1,012623	12	0,003642
10	GG	SSararb	5	0,033333	2,85E-09	5,34E-05	0,002636	847,5097	2,233693	12	0,003642
11	GG	SZararb	3	0,02	1,73E-09	4,16E-05	0,003426	508,5058	1,742103	12	0,003642
12	FF		5	0,033333	0,000102	0,010093	0,498288	160231	79841,2	22	0,688641
13	GG		144	0,96	0,000121	0,011018	0,018888	4614652	87159,54	22	0,688641
14	WW		1	0,006667	2,09E-05	0,004576	1,12947	32046,19	36195,22	22	0,688641
15	FF		258	0,948529	7,29E-07	0,000854	0,001481	421998,5	625,1732	55	0,063736
16	FF	FHI	8	0,029412	4,26E-07	0,000653	0,036534	13085,23	478,0501	55	0,063736
17	GG		6	0,022059	3,22E-07	0,000568	0,042345	9813,919	415,5688	55	0,063736
18	FF		825	0,768156	7,43E-07	0,000862	0,001846	358839,8	662,4935	56	0,066923
19	FF	FHI	5	0,004655	1,93E-08	0,000139	0,049137	2174,787	106,8634	56	0,066923
20	FG	FHD	10	0,009311	3,85E-08	0,000196	0,034664	4349,573	150,7738	56	0,066923
21	GG		232	0,216015	7,06E-07	0,00084	0,006402	100910,1	646,0335	56	0,066923

22	GG	SZararb	1	0,000931	3,88E-09	6,23E-05	0,11008	434,9573	47,88008	56	0,066923
23	WW		1	0,000931	3,88E-09	6,23E-05	0,11008	434,9573	47,88008	56	0,066923

Result after manual processing of this result using the formula, FG deforestation case, : (stratified estimate = fq_rel*wh) ; (Variance = Variance described in the table above) ; (Standard error = Square root of Variance) :

Total area	6980308,19
T student	1,645637431

lu category	**FHI**	**FHD**
Stratified estimate	0,000097	0,002371487
Variance	0,000000	6,05E-08
Standard error	0,000048	0,000246055
Margin of error (90% CI)	0,000079	0,000404918
Relative Margin of error (90% CI)	0,811774	17%
Area (ha)	678,007733	16553,71248
standard error (ha)		

* <u>Update of data by REDD+ activities on stratified estimates or estimates, standard errors through statistical results of the ADs (in the file MADA Calcul RE, DA sheet, entitled Suivi)</u>
Once the matrices from the scripts or statistical results are output, they can be used in the DA sheet by filling the estimate and standard error lines with freq_rel and std_error
*<u>Update of biomass data according to the latest inventories (Excel table, Biomasse sheet)</u>
The values of biomass, Stdev, Sample number, SE, Relative error, etc have been updated according to the results of the last forest inventory (here, it is the 2020 inventory).
Note that the formula of Veilledent et al (2012) was used for the calculation of aboveground biomass. Indeed, the development of this formula involved data from the forests of eastern Madagascar. Also, the local values obtained from local measurements are the most recommended and approximate the realities. The formula is :

$$AGB = EXP(-1.103 + 1.994 * Ln(DBH) + 0.317 * Ln\ (H) + 1.303 * Ln\ (\rho)$$

with :

AGB : Above ground biomass, expressed in tons of dry matter (tdm)

ρ : infra density of wood (t/m³)

DBH : Diameter at Breast Height (DBH) (cm)

H : Total height of the tree (m)

*<u>Calculation of the monitoring emissions itself (Excel table, Suivi sheet)</u>
The calculations of emissions or removals by REDD+ activities are done automatically according to the formulas, and the value of the monitoring emission appears automatically at the bottom (see table whose title is highlighted in green) by following the formula :
Monitoring Emission= Deforestation Emission + Degradation Emission -Absorption
Thus, the average emissions during the monitoring period are obtained, and the value of the monitoring emission appears in the first row of the column « Total annual historical GHG emissions », here it is the value <u>8,438,127 tCO2/year</u>.
It should be noted that the calculation of emissions per REDD+ activity follows the formula :

Emission (tCO2/year) = Activity Data (AD) x Emission Factors (EF)
AD: Land use change area: Example: deforestation area, obtained through data collection with the collect earth software, expressed in ha/year
EF: It is the amount of CO2 emitted when clearing 1 ha of forest, expressed in tCO2/ha and follows the following formula:
$\boldsymbol{EFj}$ = (Biomass Before,$\boldsymbol{j}$ – Biomass After,$\boldsymbol{j}$) $\boldsymbol{x\ CF\ X}$ 44/12
With
$\boldsymbol{EFj}$: Emission factor for transition j in tons CO2 ha-1.
Biomass Before,$\boldsymbol{j}$: Biomass stock before conversion from forest to non-forest stage, for transition j, in tons of dry matter ha-1
Biomass After,$\boldsymbol{j}$: Biomass stock after conversion from forest to non-forest stage, for transition j, in tons of dry matter ha-1. In the case of dead biomass, the in accordance with the IPCC recommendations for Level 1, the value was considered to be zero.
$\boldsymbol{CF}$: Fraction of carbon in dry biomass.
44/12 : Carbon expansion factor at CO2.

-Calculation of the Emission Reduction
*Update the monitoring period (expressed in days) in the Excel table, Reduction d'émission sheet
This update or calculation of the number of monitoring days will be necessary if the monitoring period does not cover a full year, i.e. different from 360 days, and if the monitoring period starts for example in the middle of the year (here, beginning of the period = March 22, 2020). The calculation of the number of monitoring days is as follows : (December 31, 2020-March 22, 2020)+1 = 285 days (see line entitled Length of the Reporting period/Length of the Monitoring Period (# days/# days)
*Update the different parameters of the table to have the number of emission reductions to sell
These parameters are designated by the letters A, B, C, D, E, F, G, H, I, J, K, L
The value of these parameters are obtained either in the MR (example : 28%, Total reversal risk) or in the Monte Carlo excel file (example : 8% conservativeness factor designated uncertainty discount)

Table 8: Estimation of emissions by sources and removals by sinks

Total emissions for the monitoring period are calculated as the sum of emissions from deforestation, emissions from forest degradation minus removals.

Emission for monitoring period = 7,731,616 + 706,511+0 = 8,438,127 tCO2e/year

Year of Monitoring/Reporting Period	**Emissions from deforestation (tCO_{2-e}/yr)**	**If applicable, emissions from forest degradation (tCO_{2-e}/yr)***	**If applicable, removals by sinks (tCO_{2-e}/yr)**	**Net emissions and removals (tCO_{2-e}/yr)**
2020	7,731,616	706,511	0	8,438,127
Total	7,731,616	706,511	0	8,438,127

4.3 Calculation of emission reductions

Emission for monitoring period = 7,731,616 + 706,511 - 0 = 8,438,127 tCO2e/year
Reference level (FREL) : 11,849,654 tCO2/year
Monitored emission: 8,438,127 tCO2/year
Annual ER for the monitoring period : FREL – Monitored emission = 3,411,528 tCO2/year
ER for the report period = (Annual ER/365)*Nomber of days during the monitoring period = (3,411,528/365)*285 = 2,663,796 tCO2/year

Number of ER to FCPF= ER for the report period – Quantity of ERs to be allocated to the Uncertainty Buffer - Quantity of ERs to allocated to the Reversal Buffer – Quantity of ERs to be allocated to the Pooled Reversal Buffer = 2,663,796–213,103 –563,660– 122,534 = 1,764,499 tCO2

Table 9: Calculation of emission reductions

Total Reference Level emissions during the Monitoring Period (tCO_2-e)	11,849,654
Net emissions and removals under the ER Program during the Monitoring Period (tCO_2-e)	8,438,127
Emission Reductions during the Monitoring Period (tCO_2-e)	3,411,528
Length of the Reporting period / Length of the Monitoring Period (# days/# days)	285/365
Emission Reductions during the Reporting Period (tCO_2-e)	2,663,796

5 Uncertainty of the estimate of emission reductions

The monitoring period only covers only 285 days of 2020. Hence annual emission reductions estimate for 2020 were multiplied by 285/365 to cover that period. Since the timing of 285 days is a fixed constant and not a random variable (i.e., it does not present any standard error associated to it), no Monte Carlo component to execute this division was needed.

5.1 Identification, assessment and addressing sources of uncertainty

Table 10: Sources of uncertainty

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty	Addressed through QA/QC?	Residual uncertainty estimated?
Activity Data						
Measurement	þ	þ	This source of uncertainty applies to cases where activity data are based on sampling. This source is related to the visual interpretation of operators and/or field positioning and can be the source of both systematic and random error. This source of Error is generally high, as evidenced by recent studies. Methods for quantifying this source of Error are in the research phase and have not been applied in operational contexts. Therefore, countries will address it through robust quality control procedures that address both systematic and random errors. Robust quality control procedures include : • Written standard operating procedures including detailed labeling protocols; Indeed, there are 5 standard operating procedures that have been written, including a specific one that defines labeling, namely POS2. SOP2s are for the response design that explains how to assign labels (eg land cover/land use class) to a sample unit. The response plan allows for the best available classification of change for each sampled spatial unit and contains all the information necessary to replicate the process of assigning a label to the sampled unit. The response design defines an objective procedure that interpreters can follow that reduces interpreter bias. • Use of adequate imaging source and multiple imaging sources for labeling;	*High (bias/random)*	*YES*	*NO*

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty	Addressed through QA/QC?	Residual uncertainty estimated?
			Data collection follows a well-defined procedure, with multiple image sources available through the Collect Earth tool. In this sense, the SOP3 is established and followed by each interpreter in order to have the most reliable data possible thanks to the verification by various sources of satellite images covering the study period. SOP33 details how to set up and run data collection for sample-based visual interpretation primarily using remote sensing data to collect sample information. Google Earth, Google Earth Engine, Planet basemap and Bing map were both used. • Procedures for training interpreters to ensure proper implementation of SOPs; When collecting data to establish the measure, interpreters were trained in labelling and the actual data collection. Calibration in relation to the classification system used (Land Use and Occupation classification system, forest definitions) was also worked on beforehand. • Reinterpretation of a number of sample units to ensure that SOPs are properly implemented and to identify areas for improvement. During the measurement, a number of samples are reinterpreted at each end of collection session. For quality assurance and quality control: in general, once you fill in the information on a plot, you have to check the information included. Especially if the assigned change of cover and the classes of the two dates studied are logical. Interpreters should have the same line of reasoning and collected data should correspond. Subsequently, an operator other than the one who performed the data collection retests a random sample of 20 percent of the total number of samples during Quality Assurance. For quality control, 5 percent of the total sample plus all change classes and those with low confidence are reanalyzed by the group. /			

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty	Addressed through QA/QC?	Residual uncertainty estimated?
Representativeness	þ	Ý	The sampling is spatially balanced (stratification) and random so the sample is representative of the whole population. Hence, it is considered that this source is negligible.	*Low (bias)*	*YES*	*NO*
Sampling	ý	þ	Sampling uncertainty is the statistical variation in the area estimate for forest transitions that are reported by the ER Program. This source of Error is random, but estimator selection can be a source of Error. ER programs should use baseline data and unbiased estimators to estimate activity data and uncertainty, as recommended by the GFOI MGDFor more information on how estimates can be produced using unbiased estimates of activity data, please refer to Area Estimation FAQ and GFOI MGD Section 5.1.5 (GFOI 2016), Good Practices for Estimating Areas and Evaluating olofsson et al. Section 5.1.5 (2014). The choice of an appropriate estimator would also be a source of uncertainty that must be addressed through quality control procedures. A stratification map has been established. When drawing up this map, omission errors for the deforestation stratum were reduced as much as possible (strata studied: deforestation, forest, non-forest, gain). From this stratification map, the sampling units were generated. A pilot survey to define the appropriate number of points for estimating the area was carried out, namely 100 points or sampling units per stratum. Thus, the number of samples necessary to obtain the optimal precision was determined in stages: first a pilot study to determine the variability of the estimator and identify the initial number of samples necessary. At each step, the precision is estimated and the errors evaluated using the uncertainty calculation table (calcul_uncertainty_v6_2_20211001.xlsx), the iteration continues until the optimal uncertainty is obtained. The link is https://drive.google.com/file/d/12S0w65qtvyN5F47FVlvyqywN5TSCBFT8	*High (random / bias)*	*YES*	*YES*
Extrapolation	þ	Ý	Not applicable since no extrapolation was done, i.e. activity data was estimated directly through the sampling approach without using auxiliary data.	*L (bias)*	*YES*	*NO*
Approach 3	þ	ý	Since there is the impossibility of a non-forest land to become forest land in just one year (length of the monitoring period), this specific conversion of land cover (non-forest to forest) is not evaluated and associated errors assumed zero or negligible	*L (bias)*	*YES*	*NO*

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty	Addressed through QA/QC?	Residual uncertainty estimated?
			~~This source of error is not applicable because becoming a forest takes several years. In addition, activity data is accounted for by type of change.~~			
Emission factor						
DBH measurement	þ	þ	The error during the inventory is minimal because on one hand, the training of the team was well organized and on the other, most of the team already have experience in inventory. The diameters (DBH) are measured at chest height (1.30m) with a circumferential tape. In order to facilitate the identification of the DBH measurement height, the surveyor will obtain a 1.30 meter stick which he will attach to the trunk of the tree to be measured. The measurement error is minimal because there is already a protocol to follow, especially for the use of measuring equipment. Two types of height are recorded : total height and commercial height was : for all trees over 20 cm DBH, take both measurements and for others only the total height The height is measured using a hypsometer or vertex, following the instructions of the instrument. It can be raised with Bitterlich's Relascope To avoid errors, it is necessary to be at a distance at least equal to the height to have the two sights: the top and the foot of the tree. If the operator is located at the top of the slope, the two measurements are added and if the operator is at the bottom of the slope in relation to the tree, subtract the two targets. In the SOP on the inventory manual, there is already a diagram of the plot device to follow for the delimitation and the materialization of the plot. The forest inventory guidelines are available on REDD+ website (https://www.environnement.mg/?wpdmpro=guide-dinventaire-forestiers#) Ref: BNCCREDD+. 2020, Terrestrial Forest Inventory Manual. 25 pages. Antananarivo. Madagascar	H (bias) & L (random)	*YES*	*NO*
H measurement	þ	þ		H (bias) & L (random)	*YES*	*NO*
Plot delineation	þ	þ		H (bias) & L (random)	*YES*	*NO*

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty	Addressed through QA/QC?	Residual uncertainty estimated?
			Measurement errors are minimized by : - The establishment of a clear and precise inventory manual (BNCCREDD+. 2020, Terrestrial forest inventory manual. 25 pages. Antananarivo. Madagascar) - The recruitment of experienced staff for the inventory - The training of technicians and preparatory meeting before field missions - The use of adequate and standard equipement with all missions to minimize errors caused by instruments By quality controls carried out on random plots			
Wood density estimation	gþ	Þ	WSG (Wood Specific Gravity) values used expressed in g/cm3 have been sourced from different publications using a decision tree and strong QA/QC procedures to ensure the most accurate or conservative value. Research in Madagascar by Ramananantoandro et al. (2015) has shown that WSG values from literature overestimate measured WSG by 16% on average. However, effects on biomass estimates were found to be not significant at the 95% confidence level (c.f. section 12 of ERPD) so this has been neglected.	*Low (random)*	*YES*	*NO*
Biomass allometric model	þ	Þ	The allometric model error can be divided in the following sources. a. the error due to the uncertainty of the model's coefficients. b. the error linked to the residual model error; c. the selection of the allometric model. According to Picard et al. (2015) [†] the largest uncertainty is due to the selection of the allometric model which may be 77% of the mean biomass estimate. Van Breugel et al. (2011) [‡] estimated that the errors linked to the allometric equation could vary from 5 to35% depending on the model selected. The third	*Low (bias) & Low (random)*	*YES*	*NO*

[†] Picard et al. (2015) Error in the estimation of emission factors for forest degradation in central Africa. J For Res DOI 10.1007/s10310-015-0510-5
[‡] Van Breugel et al. (2011) Estimating carbon stock in secondary forests: Decisions and uncertainties associated with allometric biomass models. Forest Ecology and Management 262 (2011) 1648–1657

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty	Addressed through QA/QC?	Residual uncertainty estimated?
			error (c) is assumed to be negligible for the woody biomass species as these equations are calibrated with trees measured within the same ecoregion or even the ER program area. The other two errors (a and b) were found to be not significant at the 95% confidence level, so this has been neglected but they will be considered in the quantification. The allometric equation of Vieilledent et al (2012) was used to quantify aboveground biomass.			
Sampling	ý	Þ	Sampling design and implementation is one of the main sources of errors. This will be considered in the quantification of uncertainty. The measures that have been implemented to manage and reduce these sources of uncertainty are : SOP application, training of technician, QA/QC control.	*H (random / bias)*	*YES*	*YES*
Other parameters (e.g. Carbon Fraction, root-to-shoot ratios)	þ	Þ	Uncertainty from other parameters, such as root-to-shoot ratios and CF will be propagated. Selection of parameters was done in accordance with the IPCC Guidelines and guidance ensuring the most accurate or conservative estimate.	*H (bias / random)*	*YES*	*YES*
Representativeness	þ	Ý	The lack of representativeness usually causes bias, i.e. if the sample is not representative of the population. In the case of MNF this could be a source of uncertainty as the estimate is based on samples from different forest types. However, the MNF biomass stocks estimate is conservative (samples in degraded forest or single layer were not considered) in terms of reducing emissions and ERs, so it is assumed that this source of error is negligible.	*Low (bias)*	*YES*	*NO*
Integration						
Model	þ	Ý	Although the simple multiplication of AD and EF does not contain any error, there are some assumptions such as assuming that after deforestation there is an instantaneous transfer of AGB and BGB to the atmosphere or that the biomass in non-forest grows immediately after conversion. The former assumption is based on best practices, while the latter is conservative in terms of GHG emissions and emission reductions.	*Low (bias)*	*YES*	*NO*

Sources of uncertainty	Systematic	Random	Analysis of contribution to overall uncertainty	Contribution to overall uncertainty	Addressed through QA/QC?	Residual uncertainty estimated?
			Another potential source is that it is assumed that the carbon stocks of deforested forests is equal to the average of all forests, whether they are primary or not. This last assumption is partially corrected in the RL by separating the stratum of primary forest and the stratum of modified natural forest (with higher deforestation and lower biomass stocks). Another error might be the ages assumed in order to estimate the transition from non-forest to modified natural forest. This error has been taken into consideration.			
Integration	þ	Ý	This issue has been solved through the forest inventory which was based on a random sample of plots of the national grid interpreted via collect earth. This ensures the comparison of apples with apples as the emission factors are based on the forest classification observed via remote sensing, not in-situ.	*Low (bias)*	*YES*	*NO*

5.2 Uncertainty of the estimate of Emission Reductions

Monte Carlo simulation were generated using Microsoft excel spreadsheet. For each parameter described in the next table, 10,000 simulations were made which is between the recommended 5,000 to 20,000 to obtain a standard deviation within 2% of the true mean. The simulation is already stable from around 2,000 simulation and the variability is very low from around 4,000 simulations (figure below).

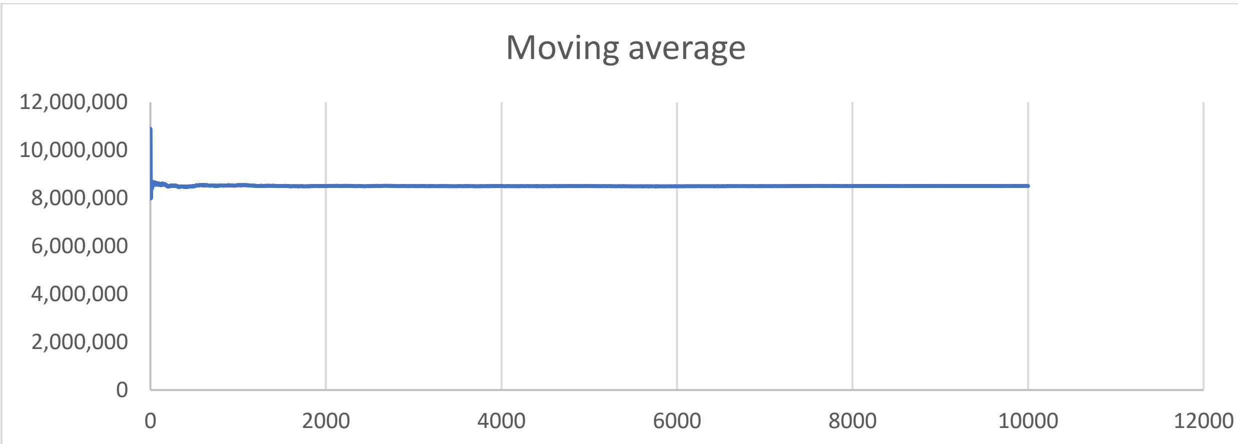


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Figure 3 : Number of iterations of the Monte Carlo simulation and the variation of the mean

Parameters and assumptions used in the Monte Carlo method

Table 11*: Parameters and assumptions used in the Monte Carlo method*

REFERENCE LEVEL				
Parameter included in the model	**Parameter values**	**Error sources quantified in the model (e.g. measurement error, model error, etc.)**	**Probability distribution function**	**Assumptions**
Annual deforestation primary forest (ha/year)	2,750.24/ SE 663.13	663.13	Normal	above zero
Annual deforestation disturbed forest (ha/year)	22,518.47/ SE 1,877.70	1,877.70	Normal	above zero
Annual deforestation secondary forest (ha/year)	160.55/ SE 160.55	160.55	Normal	above zero
Annual deforestation agroforestry (ha/year)	160.55/ SE 160.55	160.55	Normal	above zero
Annual deforestation plantation (ha/year)	0.00/ SE 0.00	0.00	Normal	above zero
Annual forest regrowth secondary forest (ha/year)	809.72/SE 356	356	Normal	above zero
Annual forest regrowth agroforestry (ha/year)	0.00/SE 0.00	0.00	Normal	above zero

Annual forest regrowth plantation (ha/year)	0.00/SE 0.00	0.00	Normal.	above zero
Annual degradation Primary forest to disturbed forest (ha/year)	11,824.64/ SE 1,355.30	1,368.14	Normal	above zero
Annual degradation Primary forest to agroforestry (ha/year)	0.00 / SE 0.00	0.00	Normal	above zero
Annual degradation Primary forest to plantation (ha/year)	0.00/ SE 0.00	0.00	Normal	above zero
Annual degradation Disturbed forest to agroforestry (ha/year)	0.00/ SE 0.00	0.00	Normal	above zero
Annual degradation Disturbed forest to plantation (ha/year)	0.00/ SE 0.00	0.00	Normal	above zero
AGB primary forest (tdm/ha)	202.63 / SE 8.00	8.00	Normal	above zero
AGB disturbed forest (tdm/ha)	186.00 / SE 12.14	12.14	Normal	above zero
AGB secondary forest (tdm/ha)	91.11 / SE 15.88	15.88	Normal	above zero
AGB agroforestry (tdm/ha)	87.87 / SE 7.64	7.64	Normal	above zero
AGB plantations (tdm/ha)	29.55 / SE 6.25	6.25	Normal	above zero
AGB non-forest (tdm/ha)	11.96 / SE 3.28	3.28	Normal	above zero
RSR >125 tdm/ha (dimensionless)	0.24 / range 0.22-0.33	Sampling error	Uniform	No assumption
RSR <125 tdm/ha (dimensionless)	0.20 / range 0.09–0.25		Uniform	No assumption
RSR Eucalyptus (dimensionless)	3.24/ range 2.74-4.26		Uniform	No assumption
SOCbefore (tC/ha)	110.97 / SE 6.26	6.26	Normal	above zero
SOCafter (tC/ha)	104.65 / SE 6.13	6.13	Normal	above zero
FMG Deforestation (dimensionless)	1.22 / SE 0.09	0.09	Normal	above zero
FI Deforestation (dimensionless)	0.92 / SE 0.13	0.13	Normal	above zero
D Deforestation (dimensionless)	1.00 / SE ##		Normal	above zero
Dead wood content deforestation primary forest (tdm/ha)	12.93 / SE 1.34	1.34	Normal	above zero
Dead wood content deforestation disturbed forest (tdm/ha)	12.13 / SE 0.88	0.88	Normal	above zero
Dead wood content deforestation secondary forest (tdm/ha)	10.61/ SE 5.56	5.56	Normal	above zero

Dead wood content deforestation agroforestry (tdm/ha)	10.88/ SE 5.7	5.70	Normal	above zero
Dead wood content deforestation plantation (tdm/ha)	0.00 / SE 0.00	0.00	Normal	above zero
Dead wood content deforestation non forest (tdm/ha)	0.00/ SE 0.00	0.00	Normal	above zero
Litter content deforestation - forest (tC/ha)	2.10 /range 1.00-3.00		Uniform	No assumption
Litter content deforestation - non forest (tC/ha)	0.00 /range 0.00-0.00		Uniform	No assumption
Combustion factor - Primary tropical forest-Non-CO2 emissions (dimensionless) (slash and burn)	0.50 /SE 0.03	0.03	Normal	above zero
Secondary tropical forest (slash and burn) -Non-CO2 emissions (dimensionless)	0.55 /SE 0.06	0.06	Normal	above zero
Emission factor CH4 Tropical forest-Non-CO2 emissions (g/kg)	6.80 / SE 2.00	2.00	Normal	above zero
Emission factor N2OTropical forest-Non-CO2 emissions (g/kg)	0.20 /SE 0.10	0.10	Normal	above zero
Age secondary forest-Forest gain (year)	20.00 /range 12.00-18.00		Uniform	No assumption
Age agroforestry-Forest gain (year)	20.00 /range 12.00-18.00		Uniform	No assumption
Age plantations-Forest gain (year)	5.00 /range 3.00-7.00	0.00	Uniform	No assumption
Age non forest-Forest gain (year)	10.00/range 3.00-7.00	0.00	Uniform	No assumption
CF (Carbon fraction, Tropical and subtropical ; all)	0.47 /range 0.44-0.49	NA	Uniform	No assumption
Conversion Factor to CO2	3.67	NA	NA	NA
Reference period (year)	10.00	NA	NA	NA
GWP (CH4)	28.00	NA	NA	NA
GWP (N2O)	265.00	NA	NA	NA
MONITORING				
Annual deforestation primary forest (ha/year)	678 / SE 334.45	334.45	Normal	Above zero

Annual deforestation disturbed forest (ha/year)	16,553.71 / SE 1,717.54	1,680.53	Normal	Above zero
Annual deforestation secondary forest (ha/year)	0.00 / SE 0.00	0.00	Normal	Above zero
Annual deforestation agroforestry (ha/year)	0.00 / SE 0.00	0.00	Normal	Above zero
Annual deforestation plantation (ha/year)	0.00 / SE 0.00	0.00	Normal	Above zero
Annual forest regrowth-Forest gain-secondary forest (ha/year)	0.00 / SE 0.00	0.00	Normal	Above zero
Annual forest regrowth-Forest gain-agroforestry (ha/year)	0.00 / SE 0.00	0.00	Normal	Above zero
Annual forest regrowth-Forest gain-plantation (ha/year)	0.00 / SE 0.00	0.00	Normal	Above zero
Annual degradation-Primary forest to disturbed forest (ha/year)	19,888.22 / SE 6,221.55	6,221.55	Normal	Above zero
Annual degradation-Primary forest to agroforestry (ha/year)	0.00/ SE 0.00	0.00	Normal	Above zero
Annual degradation-Primary forest to plantation (ha/year)	0.00/ SE 0.00	0.00	Normal	Above zero
Annual degradation-Disturbed forest to agroforestry (ha/year)	0.00/ SE 0.00	0.00	Normal	Above zero
Annual degradation-Disturbed forest to plantation (ha/year)	0.00/ SE 0.00	0.00	Normal	Above zero

Quantification of the uncertainty of the estimate of Emission Reductions

Table 1 : Quantification of the uncertainty of the estimate of Emission Reductions

		Reporting Period		**Crediting Period**	
		Total Emission Reductions*	**Forest degradation****	**Total Emission Reductions***	**Forest degradation****
A	**Median**	3,816,113	NA	3,816,113	NA
B	**Upper bound 90% CI** (Percentile 0.95)	6,078,450	NA	6,078,450	NA
C	**Lower bound 90% CI** (Percentile 0.05)	1,655,000	NA	1,655,000	NA
D	**Half Width Confidence Interval at 90% (B – C / 2)**	2,211,725	NA	2,211,725	NA
E	**Relative margin (D / A)**	58%	NA	58%	NA
F	**Uncertainty discount**	8%	NA	8%	NA.

*Remove forest degradation from the estimate if forest degradation has been estimated with proxy data.

**Remove the column if forest degradation has not been estimated using proxy data.

5.3 Sensitivity analysis and identification of areas of improvement of MRV systems

Referring to criterion 7 and indicators 9.2 and 9.3 of the Methodological Framework and the Guideline on the application of the Methodological Framework Number 4 On Uncertainty Analysis of Emission Reductions, a sensitivity analysis was undertaken to identify the relative contribution of each parameter to the overall uncertainty. Sensitivity analysis was undertaken by systematically disabling a parameter and noting the change in overall uncertainty of the emission reduction. This process was done by turning the parameter off (changing from include parameter = YES to include parameter = NO, noting the parameters and putting the parameter back on before moving to the next parameter, this scenario assumes the parameter is error free permitting the enhancement to the uncertainty provided by that parameter.

Table 12: Sensitivity analysis (lists only the parameters that can be controlled by the project)

Scenario	Uncertainty 90% CI	Difference to ER Uncertainty 90% of all parameter
All parameters	56	0
No reference level Deforestation	41	-15
No reference level Degradation	56	0
No reference level Enhancement	56	0
No Emission factor	52	-4
No Root to shoot ratio	56	0
No monitoring level deforestation	46	-10
No monitoring level degradation	55	-1
No monitoring level Enhancement	56	0

The difference of uncertainty compared to ER overall uncertainty are all below the threshold of 20%. However, deforestation from both reference period and monitoring period has the highest contribution to the error rate. This may be due to the fact that deforestation represent only a small fraction of the landscape and it is disproportionate to put a lot of samples in the deforestation class without the sample being too close to one another or overlapping. We will still try to monitor this parameter closely in the next monitoring period. All the other parameters have very low imprecision and the difference from including or excluding the parameter did not add more value to the uncertainty.

6 Transfert of title to ers

6.1 Ability to transfer title

For Madagascar, the title of ERs is the State property according to the provisions of Decree No. 2013-785 of October 22, 2013 setting the terms and conditions regarding the delegation of State forests management to public or private persons in its Article 52, which stipulates that "All woody and non-woody forest products, tangible or intangible, including forest carbons, remain the property of the State, the management of which is the exclusive responsibility of the Forestry Administration."

Decree No. 2018-500 of May 30, 2018 adopting the National REDD+ Strategy in Madagascar, specifies that the "property right on carbon" is exclusively the property of the State, through the forestry administration. The contractualization of an emission reduction payment agreement and the principle of sharing the revenues obtained, is the prerogative of the State.

The Decree No. 2021-113 on the regulation of market access also confirms this exclusivity of the State in the transfer of the ERs titles.

Please refer to the legal note: https://www.environnement.mg/?wpdmpro=note-juridique-sur-le-transfert-des-titres#

6.2 Implementation and operation of Program and Projects Data Management System

Another system called "Information System on REDD+ Initiatives and Programs" (temporarily unavailable due to end of hosting contract) has been set up to manage the existence of projects and ensure that initiatives developed do not overlap. This system assists in the implementation and monitoring of field activities but does not generate or manage any RE Unit or title.

Description of the Information System on REDD+ Program and Initiatives

Based on the Decree on the regulation of access to the forest carbon market, Madagascar has developed its own national system called the REDD + Initiatives and Programs Information System (SIIP) http://siip.bnc-redd.mg/. The system was based on the REDD+ Program Environmental and Social Safeguard Information System (SIS http://sis.bnc-redd.mg/) that has been created since 2017. This is in line with what was set in the program's ERPD. Currently, the SIIP is operational and hosted within the BNCCREDD+. The system is available in French and is freely accessible online.

The SIIP makes it possible to collect, process, consolidate, classify and disseminate all information related to the management, monitoring and evaluation of REDD+ Programs and Initiatives.

The BNCCREDD+ ensures the administration, maintenance and security of the SIIP.

The database consists of the following 4 main elements:

- Information on the initiatives' backups (SIS)

The data includes the backup activities of each initiative and the related completion reports, which are necessary for monitoring the activities.

- Information on REDD+ related complaints

A section of the SIIP is reserved for complaints, which will be presented in a table displaying - among other things - the description of each one of them and their status (received, processed, etc.).

Each complaint is referenced according to the Region concerned and a serial number.

Complaint forms, response forms and other files related to the complaint are available as attachments.

- Information on accredited initiatives

These elements concern the initiatives description (map, characteristics, activities, investment plan) and the approval situations of existing REDD+ initiatives with the related acts.

The Financing Contracts, which are contractual documents between the initiative promoter and the BNCCREDD+, allowing for the initiative's utilization plan to be financed when sharing the benefits, are also included.

The carbon benefit utilization plans established by each initiative are also posted.

− Information on monitoring and evaluation of initiative performance.

This part concerns the reports on the realization of each initiative and their performance (carbon, non-carbon, effort) according to the evaluations carried out by the BNCCREDD+.

How the SIIP works

Upstream, the system is managed by a Super Administrator (BNCCREDD+) who ensures the backup and restoration of the site.

The Administrator who is the Webmaster / Moderator (BNCCREDD+) ensures the content total management: addition, deletion, modification, publication; as well as the users and interfaces management.

The Operators who are the BNCCREDD+ managers and the RRCs ensure the content entry (addition, deletion and modification according to privileges) and the final data integration.

The initiatives and the RRCs are the authenticated users who make conditional additions of elements (without publication, the additions await the validation of the administrators), conditional modification of information: according to privileges and conditional consultation of specific information.

Downstream, there is the public or visitors. They can consult and download information published in the SIIP.

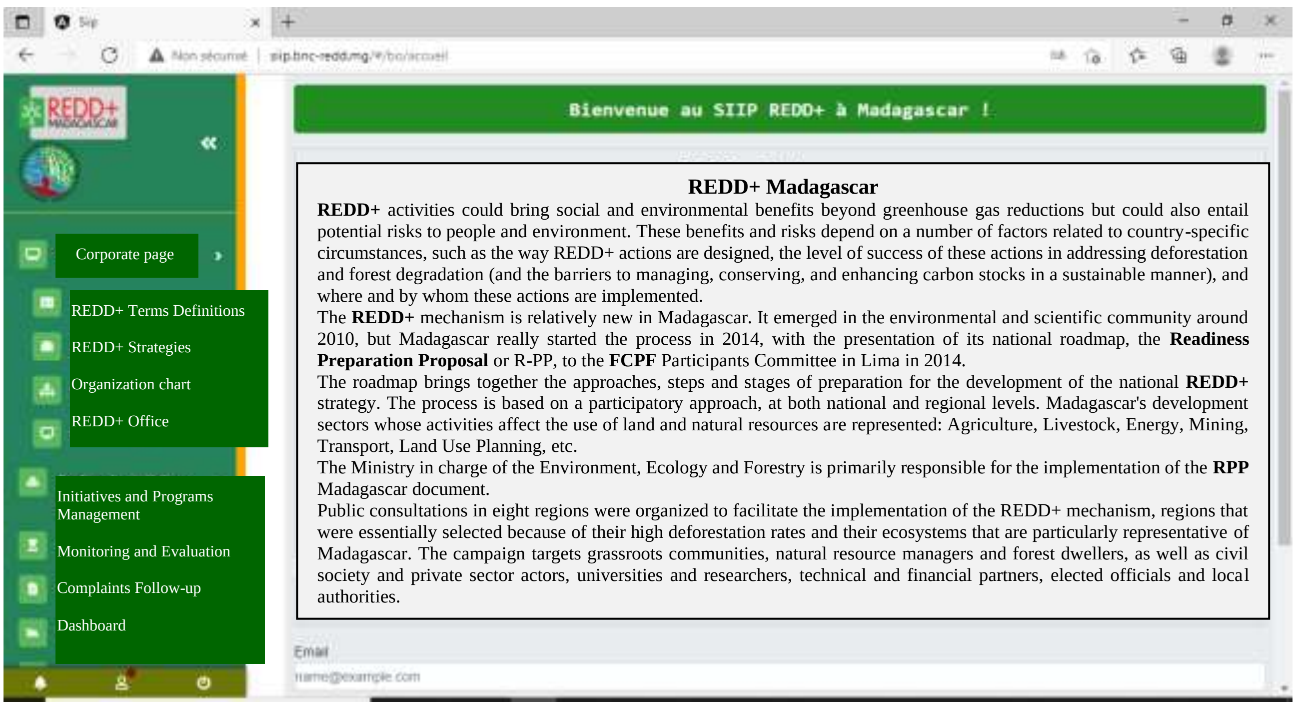

Figure 4 : REDD+ Initiatives and Program Information System Interface

6.3 Implementation and operation of ER transaction registry

The ER title is an administrative act signed by the Director General in charge of forests, according to Art 7 of Decree 2021. The Ministry in charge of forests issues an official document certifying ER verification to generate a legal title. The ER title is based on "the ER volume in the verification report mandated by the buyer". It will be produced 15 days after the verification report has been officially issued. This ER title is very specific to Madagascar, as it also contains the performance by "REDD+ initiative" (which constitutes the ERP AA), used for benefit sharing between initiatives according to their performance.

For ERs generated under Atiala Atsinanana Emission Reduction Program, Madagascar agrees to use the FCPF CATS registry to manage the Program's certified ER units. The process with the buyer is done in 2 steps:

1. ER title creation (paper document), (ii) then registration of the ER volume in the transactional register in the State's ACCOUNT (owner)

2. Issuance of the ER transfer order to the buyer (paper document), signed by the MEF and the MEDD. This document is sent to the buyer and to the transactional registry manager

It should also be noted that only the Government through the Ministry of the Environment has the capacity to sign payment agreements and to market Emission Reductions. It is this same entity that carries out the validation of carbon projects (including on voluntary markets), and which also makes the corresponding adjustment related to the NDC to avoid double counting.

6.4 ERs transferred to other entities or other schemes

The terms of the payment contract for the Atiala Atsinanana Program provide for an 85/15 split on volume during a reporting period, meaning that 85% of the ERs generated under the ER program du/ring a reporting period must be transferred to the trustee as contract ER, and the remaining 15% of the ERs generated can be used by the country for other purposes. However, for the relevant notification period, Madagascar does not plan to sell any volume of ER from the Program to other buyers

In the program area, for a period prior to the Atiala Atsinanana Program and ERPA, Makira Park and CAZ were REDD+ pilot projects and commercialized certified ERs. Informations identified on the VERRA registry concerns ERs generated from 2005 to 2013 for Makira, and from 2009 to 2012 for CAZ. Currently, there is no overlap with other programs for these two sites and both initiatives have been integrated and accounted under the Atiala Atsinanana Program for the ERPA period.

7 Reversals

7.1 Occurrence of major events or changes in the ER Program circumstances that might have led to the Reversals during the Reporting Period compared to the previous Reporting Period(s)

As this is the first monitoring period, there is no "previous" monitoring period and there is no reversals. Hence, section 7.1 not applicable

7.2 Quantification of Reversals during the Reporting Period

As this is the first monitoring period, there is no "previous" monitoring period and there is no reversals. Hence, section 7.2 not applicable

7.3 Reversal risk assessment

The reversal risk assessment using the Buffer Guidelines has not changed since the preparation of the ERP-AA final ERPD. Therefore, no risk other than the 4 listed in the Buffer Guidelines has been identified.

The program lasts for 5 years and actually, the largest payment of ERs from the program comes at the end of the third period, i.e. beyond the duration of the ERPA. These funds are intended to sustain the activities carried out under the program, including those that strengthen community livelihoods and reduce the risks of reversal.

Indeed, the Program's benefit-sharing plan provides for the use of carbon revenues to sustain and increase the Program's activities both during the Program and beyond.

It is also important to note that the governance of the REDD+ mechanism and the Program was designed purposely to enhance existing structures (public and administrative structures), mobilizing local actors (based communities and delegated managers) and ensuring that at the end of the Program, all structures and capacities remain and continue to operate.

The assessment of natural and anthropogenic risks of reversals thatr was conducted following the FCPF Buffer Guidelines and the four main risk factors described:

- Lack of broad and sustained stakeholder support
- Lack of institutional capacities and/or ineffective vertical/cross sectorial coordination
- Lack of long term effectiveness in addressing underlying drivers
- Exposure and vulnerability to natural disturbances

More generally, the focus on watersheds is designed to be inclusive of populations in contiguous communities thus limiting the most immediate risk of incursions from neighboring populations. These natural geographic/geolo.gic target groups (watersheds) provide a degree of natural impediment to largescale population influxes, and also enable program design that is tailored to each program area, with the identified activities.

Table 13: Reversal risk assessment

Risk Factor	Risk indicators	Default Reversal Risk Set-Aside Percentage	Discount	Resulting reversal risk set-aside percentage
Default risk	*N/A*	**10%**	*N/A*	*10%*
Lack of broad and sustained stakeholder support	As explained in section 5.1, consultations in the jurisdiction have been intensive and realized in each region of the program through the five Regional REDD+ Platforms that participated in the general design of the program, including its strategy,	**10%**	*Low risk: 10%*	0%

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	institutional arrangements, eligible and planned activities, FGRM and safeguards mechanism, and most recently, activity selection and prioritization by commune. In addition, specific consultations were carried out at the commune level during the different studies performed (see section 5). When looking at the number of stakeholders by taking into account the different REDD+ platforms, technical groups, and thematic workshops, over 500 persons have been deeply involved into the design of the general strategy of the program to reduce deforestation, and all communes of the program have been consulted at least once. Also, in some area of the ER-P (Makira and CAZ), stakeholders already have a positive experience with REDD+ and their related supporting mechanisms such as benefit sharing, FGRM and safeguards mechanisms, and thus the ER-P was developed based on these positive experiences.			
Lack of institutional capacities and/or ineffective vertical/cross sectorial coordination	Are there key institutions with experiences in implementing REDD+ project / programs? The preparation of REDD+ at national level as well as the development of the ER-P has initiated the development of strong capacities to coordinate REDD+ activities. The creation, involvement and work performed by BNC REDD+, PFN REDD+ and the PFR REDD+ illustrate the progress made in this process (most of the elements of the program described in this document have been discussed and designed with stakeholders through the platforms and with a strong support of BNC REDD+). However, these capacities mostly lie on the design phase of the REDD+ mechanism and of the program, but not on the real implementation of them. Currently there's a lack of institutional capacities at central and regional level to ensure that activities and project could be implemented, coordinated, and efficient. Mitigation measures: This is an issue on which BNC REDD+ will focus during the next months, and some capacity building activities have already begun, using the additional funds of FCPF received in 2016 (i.e. structuration of RRC's in regions and capacity building for their coordination role). It is likely that additional capacities will have to be developed or reinforced, especially within other ministries at central level, but also at sub regional level (even if an important part of capacity building will be	**10%**	*High risk : 0%*	*10%*

	ensured continuously with the strong support by TSS of communes, SLC, and PI (see section 6.1 and 15). The MEEF and BNC REDD+ are also planning to develop partnerships with other ministries in order to (i) increase their knowledge and capacities related to REDD+ (BNC REDD+ will be in charge of that), and (ii) elaborate an action plan for their involvement and role into the ER-P implementation when necessary, (iii) and identify potential external financial or technical support to ensure this role. For example, BNC REDD+ is currently working with USAID and USFS in order to leverage support from them concerning the needs of capacity building for the implementation of the NFMS and FMS. Is there a lack of cross sectoral coordination necessary for REDD+ efficiency? The creation of the PFN and PFR REDD+ illustrates that a strong effort had been provided to ensure cross sectoral coordination during the development of the ER-P. The planned institutional arrangements (described in section 6.1) for the program are also reflecting that a strong cross sectoral coordination is vital for its functioning. But currently the activities planned and described in section 4.3 are mainly coming from considerations and needs expressed by stakeholders at central, regional and local level, but they do not reflect a real commitment of concerned sectoral ministries to be responsible, even partially, for their implementation (see introduction of section 4.3). Mitigation measures: While these different ministries are represented in the REDD+ platforms, there is a need to go further in developing real partnerships with MEEF and to agree on specific action plans or procedures to ensure that activities of the program will be implemented in coherence and complementarity with activities of each relevant ministry.			
Lack of long term effectiveness in addressing underlying drivers	*Is the program able to link REDD+ to economic activities and development?* 1/ In the context of Madagascar, the main risks of ineffectiveness within the area of the project are associated with the practice of slash and burn agriculture ("Tavy") and uncontrolled extraction of wood energy. Both practices are largely associated	**5%**	*High Risk : 0%*	*5%*

	with poverty of rural households in Madagascar, a situation exacerbated during periods where households are facing food emergencies. These risks are of anthropogenic origin. Mitigation measures : The activities of the program are designed particularly to address these practices. To do so, Act AD1: (i) Development of infrastructures (construction of hydro-agricultural dam), Act AD2: (ii) Development and extension of food crops and income-generating Activities and (iii)Propagation, intensification and promotion of cash crops and agroforestry are dedicated to the improvement of agricultural practices and access to market in order to increase productivity and at the same time increase revenues of local populations, allowing them to progressively reduce their dependency on subsistence agriculture. 2/ The commodities driving deforestation are products from permanent crops: vanilla, cloves, and coffee, high value products that are generating higher incomes to households and have a positive impact on the local economy. During the reference period, these commodities had a two-faceted impact on deforestation: on one hand, it can incentivize local populations to cut forest parcels in order to implement production; on the other hand, such production is also implemented on fallow land or secondary forest, allowing their maturation and increasing carbon stocks on land with relatively low carbon content. Mitigation measure: The program will implement measures to reduce the risk that such commodities trigger deforestation and are systematically produced under agroforestry systems, thus participating in carbon stock enhancement when settled on fallow land or secondary forest. Most of the protected areas are already fostering such practices within their surrounding agriculture belt, with positive experiences and feedbacks, and the PADAP will also implement agroforestry in 3 watersheds of the program. Activity AD2 of the ER-P is dedicated to agroforestry, and more globally, the program will try to increase sustainable production of commodities within the jurisdiction			

	3/ An additional risk, identified through experience, is that success in the project/program areas, if associated with important positive economic impact, can lead to influx of people that are not part of the target population thus leading to unsustainable practices in the end. This context is particularly witnessed in projects/programs of relatively short lifespan. Mitigation measures: The ER Program design focuses on the development of activities that can be inclusive of incoming populations through identification and promotion of "no-land" activities, income-generating activities that are not dependent on land ownership, and will limit anarchic land grabs that may be associated with these practices. "No-land" activities are designed to strengthen the value chains that will reduce pressures on forest degradation directly and also indirectly through decreasing the demand for extensive land practices. Is relevant legal and regulatory environment conducive to REDD+ objectives? The government of Madagascar has taken several legal and regulatory steps to integrate REDD+ into the legal framework for environment and climate change mitigation in the country. Several legal steps, described in section 4.5, have recently clarified key legal and institutional elements of REDD+ and have created a sufficient basis on which to plan implementation. In addition, Madagascar's previous experience with project-level carbon finance has provided legal precedence and procedures which have informed, and in some cases provided the foundation for, structures currently in design or finalized for the ER-P.			
Exposure and vulnerability to natural disturbances	*Risks due to natural forest fire.* The project area is a humid rainforest habitat. Natural fires in Madagascar are mostly limited to savannah habi/tats. There is no reference or available information of natural fire resulting in large-scale deforestation in the humid forest of Madagascar. All fires are, according to literature, due to human activities in this part of the country. Cyclone damage can enable fire propagation but the origins of fires are largely anthropogenic. *Risks due to pests and disease*	**5%**	*Medium risk : 2%*	*3%*

	No major pest or disease outbreaks leading to die-off of forest have been recorded in rainforests in Madagascar. Large-scale tree pest and disease outbreaks are extremely rare in tropical natural forests due to the high diversity of tree species and low densities that are typical (Nair, 2007). *Risks of extreme climate events that could contribute to deforestation.* The only extreme climate events recorded on the east coast of Madagascar are cyclones. Since the beginning of the twenty-first century, four major cyclones reached the eastern coast of Madagascar and the area of the ER-P causing important damages to local population. However, very little information is available on the actual impact of cyclones on the eastern ecosystems. The majority of cyclones lose their destructive power by the time they get as far inland as the CAZ project area for example (World Bank, 2008). Even if they are powerful, the area of damage to forest is relatively limited. Native forest also recovers well following cyclone damage in the absence of anthropogenic threats, as cyclones are a natural phenomenon of the ecology of these forests (Birkinshaw, 2007). Even in an extremely powerful cyclone, less than 10% of carbon stocks of the ER-P are likely to be lost and the loss will be transient with good recovery. For example, cyclone Hudah, one of the most powerful cyclones to damage forests in Madagascar in the last 15 years, was estimated to have damaged 3.2% of the 143,236 hectares of forests of the Masoala peninsula (Birkinshaw, 2007). However, Masoala is a coastal area and therefore cyclone impact at CAZ would be expected to be much less since the cyclone's power reduces over land (Birkinshaw, 2007; World Bank, 2008).			

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Total reversal risk set-aside percentage	*28%*
Total reversal risk set-aside percentage from ER-PD or previous monitoring report (whichever is more recent)	28%

8 Emission reductions avalaible for transfer to the carbon fund

Table 14: ERs available for transfer to the Carbon Fund

A.	**Emission Reductions during the Reporting period (tCO_2-e)**	*from section **Error! Reference source not found.***	2,663,796
B.	**If applicable, number of Emission Reductions from reducing forest degradation that have been estimated using proxy-based estimation approaches (use zero if not applicable)**		0
C.	**Number of Emission Reductions estimated using measurement approaches (A-B)**		2,663,796
D.	**Percentage of ERs (A) for which the ability to transfer Title to ERs is clear or uncontested**	*from section 6.1*	100%
E.	**ERs sold, assigned or otherwise used by any other entity for sale, public relations, compliance or any other purpose including ERs accounted separately under other GHG accounting schemes or ERs that have been set-aside to meet Reversal management requirements under other GHG accounting schemes**	*from section 6.4*	0%
F.	**Total ERs (B+C)*D-E**		2,663,796
G.	**Conservativeness Factor to reflect the level of uncertainty from non-proxy based approaches associated with the estimation of ERs during the Crediting Period**	*from section 5.2*	8%
H.	**Quantity of ERs to be allocated to the Uncertainty Buffer (0.15*B/A*F)+(G*C/A*F)**		213,103
I.	**Total reversal risk set-aside percentage applied to the ER program**	*from section 7.3*	28%
J.	**Quantity of ERs to allocated to the Reversal Buffer (F-H)*(I-5%)**		563,660
K.	**Quantity of ERs to be allocated to the Pooled Reversal Buffer (F-H)*5%**		122,534
L.	**Number of FCPF ERs (F- H – J – K)**		1,764,499

ANNEX 1: INFORMATION ON THE IMPLEMENTATION OF THE SAFEGUARDS PLANS

ANNEX 2: INFORMATION ON THE IMPLEMENTATION OF THE BENEFIT-SHARING PLAN

ANNEX 3: INFORMATION ON THE GENERATION AND/OR ENHANCEMENT OF PRIORITY NON-CARBON BENEFITS

ANNEX 4 : CARBON ACCOUNTING-Addendum to the ERPD

Technical corrections

Technical corrections have been observed in particular in part 3.1 “Fixed data and parameters”.

The technical corrections concern :

- Revision of the reference level (RL), by reassessment of activity data. This measure was taken since there is a clear improvement in the availability of images allowing for more precision on the land use classes, thus resulting in a reduction in errors. Also, the analysts had more experience and knowledge especially on the definition of Land Use and Occupation (https://www.environnement.mg)
- Revision of emission factors (EF), previously allometric formulas from Vieilledent were used for both dry forests and studies published by Vieilledent for humid forests. A forest inventory and more local and more precise EF calculations were made in collaboration with the DRGPFVRF and the MEDD.

Start Date of the Crediting Period

As per the signed ERPA, the start date of the Crediting Period start date for the ERP-AA is 22th March, 2020.
This date meets the definition of the Start Date of the Crediting Period provided in the FCPF Glossary of Terms as Follows :
• It is not earlier than June 2018, date of program inclusion into the carbon fund portfolio
• It does not fall within the Reference period 2006-2015.
• The ER Program complies with requirements since the start date on safeguards (see Annex I of this report), carbon accounting (section 4 of this report) and double-counting (section 6 of this report)

Summary of technical corrections

The technical corrections made are mainly the update of the activity data and emission factors according to the systematic national grid with a step of 4 km x 4 km. Previously, the collection of activity data was based on stratified random sampling and currently the points of the national grid are simply used as a sample to define the reference level and the new definition of forests fixing the minimum area at 0.5ha instead of 1ha as well as the use of the land use and occupation (UOT) classification system (https://www.environnement.mg). The biomass data come from the last inventory carried out in 2020. The inventory plots are units determined randomly in relation to the national grid according to the stratum concerned. The last definition was from FAO but it was a standard definition for a country. However, Madagascar creates an own definition related a REDD+. It was an exchange with a technical responsible of FCPF. This is part of the implementation of the national standard.
This technical correction has already been notified by FCPF in the annual report of the 2019 preparation fund and there was no objection from the FCPF.

7 Carbon pools, sources and sinks

7.1 Description of Sources and sinks selected

Table 15: Sources and sinks selected

Sources/Sinks	**Included?**	**Justification/Explanation**
Emissions from deforestation	Yes	Monitoring and reducing deforestation is the main focus of the proposed REDD+ program. According to CM Indicator 3.2, emergency programs must address deforestation. Emissions from deforestation are identified as GHG emissions in the IPCC land use change category (from forest to non-forest land).

		According to the key category analysis, GHG emissions from deforestation account for 94% of total forest-related GHG emissions.
Emissions from forest degradation	Yes	The ER program assessed also emissions from degradation. The land use change patterns in the ER program result in deforestation, and degradation. The land use change analysis indicates that annual areas of 11,826 ha are transformed from primary to degraded humid forest during the reference period. Assuming a simplified emission factor for degradation that is determined as the difference between the carbon stocks of primary and degraded humid forest, this results in an average carbon stock change of 35.52 tCO_2/ha. Using this emission factor, total annual emissions would be 420,060 tCO_2. According to the key category analysis, GHG emissions from forest degradation represent 5% of total net GHG emissions or 5% of total absolute GHG emissions and removals.
Removal as a result of improved carbon stocks	Yes	The ER program accounts for GHG removals from the conversion of non-forest land to forest land as defined by the IPCC, whether through natural regeneration or new plantations. According to the key category analysis, GHG removals for reforestation/reafforestation represent 1% of total forest-related emissions. The enhancement of carbon stocks in forest lands that remain forested was not considered due to lack of data.
Emissions and removals from carbon stock conservation	No	There is no national definition for this REDD+ activity. However, there is comprehensive accounting for GHG emissions and removals from forests so that GHG emissions and removals that may be included in this activity are included in previous REDD+ activities.
Emissions and removals from sustainable forest management	No	There is no national definition for this REDD+ activity. However, there is comprehensive accounting for GHG emissions and removals from forests so that GHG emissions and removals that could be included in this activity are included in previous REDD+ activities.

7.2 Description of carbon pools and greenhouse gases selected

Table 16 : Selected greenhouse gases and carbon pools

Carbon pools	Selected?	Justification/Explanation
Above-ground biomass (AGB)	Yes	Based on the key category analysis, emissions from AGB account for 68% of GHG emissions from all forest-related GHG emissions (i.e., more than 10% of total forest-related emissions in the accounting area during the reference period). This carbon pool is a major contributor to emissions, but if successful, it can also contribute to the emissions reductions of the proposed ER program. Therefore, emissions from this pool are included.
Below-ground biomass (BGB)	Yes	The ER program uses root system/shoot system coefficients with an order of magnitude of 20-25% of BGB. Based on the key category analysis, this represents 16% of total forest-related GHG emissions. Thus, emissions from the BGB pool are significant (i.e., more than 10% of total forest-related emissions). Therefore, this group is included in the accounting of overall emissions as well as emission reductions.
Dead wood	Yes	Emissions from the dead wood pool (standing dead wood) are counted because they are already included in the aboveground biomass pool.
Litter	Yes	Litter accounts for 5% of total forest-related GHG emissions. Litter and SOC account for over 10% of total forest-related GHG emissions.
Soil Organic Carbon (SOC)	Yes	Based on the key category analysis, GHG emissions and removals from the SOC group account for 6% of total forest-related GHG emissions. Litter and SOC account for over 10% of total forest-related GHG emissions.

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GHG	Selected?	Justification/Explanation
CO_2	*Yes*	The ER Program must always consider CO2 emissions and removals. CO2 is the most important part of the emissions from deforestation in Madagascar, mainly due to slash and burn agriculture.
CH_4	*Yes*	Non-CO2 GHG emissions from deforestation account for 4% of total absolute GHG emissions.
N_2O	*Yes*	Non-CO2 GHG emissions from deforestation account for 4% of total absolute GHG emissions.

8 Reference level

8.1 Reference period

The reference period for the ER program is from January 01, 2006 to December 31, 2015. It therefore covers approximately 10 years. As such, the reference period is considered to be consistent with CM Criterion 11 and therefore no justification is required.

8.2 Forest definition used in the construction of the Reference Level

a. **Forest definition**

The Designated National Authority (DNA) [§] of Madagascar has submitted a definition of forest to the UNFCCC for reforestation/reafforestation projects under the CDM (Clean Development Mechanism). This definition is consistent with the definition used in the national communication submitted in 2010[**]. In 2018, a workshop was held for the new forest definition and a related document was released in May 2018. This same forest definition was used for the forest reference emission level (FERL) for the ERPAA program and for the national FERL update.

Table 17: Thresholds of the forest definition in Madagascar

Forest types	*Minimum area (ha)*	*Minimum canopy cover (%)*	*Minimum tree height (m)*
Wet and dry, plantation and agroforestry	0.5	30%	5
Xerophilous thickets	0.5	30%	2
Mangroves	0.5	10%	2

In the 2015 Forest Resources Assesssment (FRA) submission, evergreen forest and other forest classes from the 1996 National Forest Inventory (NFI96) were used as an equivalence to the FAO [††] forest definition. Such a classification is an ecological one based primarily on phytogeographic characteristics and vegetation height. As part of the NFMS development process, new values will be reported and equivalence to the FAO definition will be established.

b. ***Definition of REDD+ activities***

In April 2016, Madagascar decided on preliminary definitions for the different REDD+ activities deemed applicable to the country.

Table 18: Definitions of REDD+ activities approved by Madagascar

Activity	**Definition**
Deforestation	A direct human-induced conversion of forested land to non-forested land, with a continuous area of at least 0.36 ha, temporary or permanent. For example, conversion of primary forest to tavy land would constitute deforestation even if the conversion is temporary. Conversion of secondary forest to non-forest land would also constitute deforestation.
Forest Degradation	Reduction in forest carbon stocks due to anthropogenic disturbances resulting from canopy loss, not classified as deforestation. For example: forest degradation represents a gross loss of forest carbon in a mature forest.
Carbon stock enhancement	Increase in forest carbon stocks, either through a transition from non-forest to forest land, or through the growth and/or restoration of existing forests.

[§] Http://cdm.unfccc.int/DNA/index.html

[**] BNCCC. 2017. Personal communication

[††] Http://www.fao.org/3/a-az264f.pdf

OPERATIONALIZATION OF REDD+ ACTIVITIES

Since only deforestation and carbon stock improvement in new forests are included, the operationalization of the forest definition was done as follows:

- Deforestation:
  - Human-induced: natural losses due to cyclones, usually at high-altitude ridge tops.
  - Minimal area: sampling units on 30 meters squares are used to collect sample reference data. If a forest has been found to have fallen below the 30% canopy cover threshold, this will be considered as deforestation if such loss occurs in a continuous area of at least 0.36 ha.
  - Permanent VS temporal loss: it is unlikely that the loss of forest cover that occurs in the 10-year reference period will reach the forest threshold. Therefore, it is assumed that the conversion is permanent. If after 10 years the forest grows back, this will be considered a stock improvement.
  - Plantations: conversion of plantations to non-forest land has not been included in the RL.
- Enhancement of carbon stocks:
  - Minimal area: 30-meter side-square sampling units are used to collect sample reference data. If it is determined that the sample has moved from less than 30% canopy cover (and it was in a non-forest area of at least 0.36 ha) to at least 30% canopy cover (and it is included in a forest area of at least 1 ha), this is considered a stock improvement.
  - Plantations: conversion of non-forest land to plantations has not been included in the RL.

In order to operationalize these definitions, the following transitions were assigned to each REDD activity:

Table 19: Attribution of transitions to each REDD activity

na = not possible; -=no changes; - = not accounted

		Land cover after conversion					
		Primary Forest	Disturbed forest	Secondary forest	Forestry plantations	Agroforestry	Non Forest
Land cover	Primary Forest	-	*Degradation*	*na*	*Degradation*	*Degradation*	*Deforestation*
	Disturbed Forest	*na*	-	*na*	*Degradation*	*Degradation*	*Deforestation*
	Secondary forest	*na*	*na*	-	-	-	*Deforestation*
	Forestry plantations	*na*	*na*	*na*	-	-	*Deforestation*
	Agroforestry	*na*	*na*	*na*	-	-	*Deforestation*
	Non forest	*na*	*na*	*Enhancement*	*Enhancement*	*Enhancement*	-

In terms of presence of the different conversions shown above, no conversions have occurred during the reference period on deforestation from secondary forest, agroforestry or plantations, and the detected forest degradation has been reduced to transition from primary forest to disturbed forest. In order to comply with the Cancun agreements, any conversion

8.3 Average annual historical emissions over the Reference period

Description of method used for calculating the average annual historical emissions over the Reference period

In accordance with the methodological framework, the ER Program was developed following the rules and methods proposed by the 2006 IPCC Good Practice Guidelines for National Greenhouse Gas Inventories. A summary of the equations and the Tier applied is provided in the following table. A more detailed description of the methods applied, assumptions, decisions and default values applied may be found further below.

Table 20: Summary of the equations and the Tier applied

Source/Sink	**Pool**	**Methods**	**Tier**
Deforestation	Biomass	Equation 2.16 and 2.8b of 2006 IPCC Volume 4 GFOI MGD, Chapter 3.1.2	Tier 2 (above-ground) Tier 1/2 (belowground)
	Dead Organic Matter (Dead wood and litter)	Equation 2.23 of 2006 IPCC Volume 4	Tier 2 (Dead wood) Tier 1 (Litter)
	Soil Organic Carbon	Equation 2.25 2006 IPCC GL Volume 4	Tier 2
	Non-CO2 emissions	Equation 2.27 2006 IPCC GL Volume 4	Tier ½
Forest Degradation	Biomass	GFOI MGD, Chapter 3.1.3	Tier 2 (above-ground) Tier 1/2 (belowground)
Enhancement of carbon stocks	Biomass	GFOI MGD, Chapter 3.1.4	Tier 2 (above-ground) Tier 1/2 (belowground)

Following these requirements the RL would be estimated as follows.

$$\mathbf{RL_t} = \sum_{i} \Delta\mathbf{C_{B,t,i}} + \Delta\boldsymbol{C_{DOM,t,i}} + \Delta\boldsymbol{C_{SOC,t,i}} + \boldsymbol{L_{fire,t,i}} \quad \text{Equation 10}$$

Where:

$\Delta\mathbf{C_{B,t,i}}$ = Changes in carbon stocks in biomass from REDD+ activity i in year t; tCO_2e $year^{-1}$.

$\Delta\boldsymbol{C_{DOM,t,i}}$ = Changes in carbon stocks in Dead wood and Litter from REDD+ activity i in year t; tCO_2e $year^{-1}$.

$\Delta\boldsymbol{C_{SOC,t,i}}$ = Changes in Soil Organic Carbon from REDD+ activity i in year t; tCO_2e $year^{-1}$.

$\boldsymbol{L_{fire,t,i}}$ = Non-CO2 emissions from fire in REDD+ activity i in year t; tCO_2e $year^{-1}$.

Equations for the estimation of the different activities, deforestation, forest degradation and enhancement of carbon stocks is provided in the next sections.

<u>Deforestation</u>

<u>Changes in carbon stocks in biomass</u>

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category (ΔC_{B_t}) would be estimated through the following equation:

$$\Delta C_{B_t} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L \quad \textbf{Equation 11}$$

Where:

ΔC_{B_t} Annual change of total biomass carbon stocks during the period, in tC per year;

ΔC_G Annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tC per hectare and year;

$\Delta C_{CONVERSION}$ Initial change in carbon stocks in biomass on land converted to other land-use category, in tC per hectare and year; and

ΔC_L Annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tC per hectare and year.

Following the recommendations set in chapter 2.5.1.1 of the GFOI Methods Guidance Document for applying IPCC Guidelines and guidance in the context of REDD+[‡‡], the above equation will be simplified and it will be assumed that:

- The annual change in total biomass carbon stocks (ΔC_B) is equal to the initial change in carbon stocks ($\Delta C_{CONVERSION}$);

Considering equation 2.16 of the 2006 IPCC GL for estimating ($\Delta C_{CONVERSION}$) the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta C_{B_t} = \sum_{j,i} \left(AGB_{Before,j} x(1 + R_j) - AGB_{After,i} x(1 + R_i)\right) \text{ x CF x} \frac{44}{12} \times \text{A(j, i)}$$ **Equation 12**

Where:

A(j, i) Area of forest converted from forest to non forest during the reference period, in hectare per year. In this case, four possible conversions are possible:

- **Primary forest to non-forest (DPF);**
- **Disturbed Forest to Non-Forest (DDF);**
- **Secondary Forest to Non-Forest (DSF);**
- **Agroforestry to Non-Forest (DAF);**
  Plantations to Non-Forest (DPL);

The description of this parameter may be found further below.

$AGB_{Before,j}$ Above-ground biomass of forest type j before conversion, in ton of dry matter per ha. This can be the above-ground biomass of the following two types of forest:

- **Primary forest (PF);**
- **Disturbed Forest (DF);**
- **Secondary Forest (SF);**
- **Agroforestry (AF);**
- **Plantations (PL);**

The description of this parameter may be found further below. **Error! Reference source not found.**

Rj ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in ton d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to:

- **0.2** is the default for tropical moist deciduous forest when above-ground biomass is <125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for Secondary Forest and Agroforestry.
- **0.24** is the default for tropical moist deciduous forest, >125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for primary forest and disturbed forest.
- **3.35** is the root shoot ratio of Eucalyptus plantations according to RAZAKAMANARIVO et al. (2013). This is the case for Plantations.

$AGB_{After,i}$ Above-ground biomass of non-forest type I after conversion, in tons dry matter per ha. This is the above-ground of **non-forest (NF)**.

The description of this parameter may be found further below**. Error! Reference source not found.**

R_i ratio of below-ground biomass to above-ground biomass for a specific vegetation type i, in ton d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to:

‡‡ https://www.reddcompass.org/mgd/resources/GFOI-MGD-3.1-en.pdf

- **0.2** is the default for tropical moist deciduous forest when above-ground biomass is <125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for non-forest.

CF Carbon fraction of dry matter in tC per ton dry matter. The value used is:

- **0.47** is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.

$44/12$ Conversion of C to CO_2

Changes in carbon stocks in Dead wood and Litter

Considering equation 2.23 of the 2006 IPCC GL for estimating ΔC_{DOM}, the change in dead organic matter carbon stocks could be expressed with the following equation.

$$\Delta C_{DOM,t} = \frac{(C_n - C_o)x\ A(j,i)\ x\frac{44}{12}}{T_{on}}$$ **Equation 13**

Where:

$A(j,i)$ area undergoing conversion from old to new land-use category, ha. This is the same as parameter $A(j,i)$ above. The description of this parameter may be found further below.

C_o dead wood/litter stock, under the old land-use category, tons C ha-1.
For dead wood it will have different values for each of the following forests:

- **Primary forest (PF);**
- **Disturbed Forest (DF);**
- **Secondary Forest (SF);**
- **Agroforestry (AF);**
- **Plantations (PL);**

For Litter, a default value for tropical broadleaf forests of **2.1** tC/ha has been used. This has been sourced from 2006 IPCC GL, TABLE 2.2, Volume 4, Chapter 4.

C_n dead wood/litter stock, under the new land-use category, tons C ha-1. It has been assumed that this is **zero**.

T_{on} time period of the transition from old to new land-use category, yr. The Tier 1 default is **1 year** for carbon losses, so it has been assumed one year.

$44/12$ Conversion of C to CO2

Changes in Soil Organic Carbon

Since in the ER program area there are only mineral soils, considering equation 2.25 of the 2006 IPCC GL for estimating ΔC_{SOC}, the change in soil organic carbon could be expressed with the following modified equation.

$$\Delta C_{SOC,t} = \frac{\sum_{\boldsymbol{j,i}}\left(\left(SOC_{Before,j} - SOC_{After,i}\right) \times \frac{44}{12} \times A(j,i)\right)}{D}$$ **Equation 14**

Where:

$A(j,i)$ land area of the stratum being estimated, ha. This is the same as parameter $\boldsymbol{A(j,i)}$ above. The description of this parameter may be found further below.

$SOC_{Before,j}$ the reference carbon stock, tons C ha-1 for forests. It has been assumed the same value for the following forest types.

- **Primary forest (PF);**
- **Disturbed Forest (DF);**

For plantations and Agroforestry it is not accounted for.

$SOC_{After,i}$ the carbon stock, tons C ha-1 for **non-forest (NF).**

$44/12$ Conversion of C to CO2

Non-CO2 emissions from deforestation

Following the Equation 2.27 of Volume 4 of the 2006 IPCC GL, GHG emissions from forest fires are estimated with the following equation:

$$L_{fire,t} = A x M_B x C_f x G_{ef} x 10^{-3}$$ **Equation 15**

Where :

A area burnt, ha, which is equivalent to $A(j,i)$ Area of forest converted from forest to non-forest during the monitoring period, in hectare per year. The description of this parameter may be found further below. This could be the following conversions:

- **Primary forest to non-forest (DPF);**
- **Disturbed Forest to Non-Forest (DDF)**
- **Secondary Forest to Non-Forest (DSF)**
- **Agroforestry to Non-Forest (DAF)**
- **Plantations to Non-Forest (DPL)**

M_B mass of fuel available for combustion, tons ha-1. This is equivalent to the biomass prior to conversion $\boldsymbol{AGB_j}$. This is the above-ground biomass in forest areas as afforestation/reforestation does not involve burning prior to conversion.

C_f combustion factor, dimensionless. This is equal to:

- **0.5** for primary forest, as it is the value for primary tropical forest (slash and burn) according to 2006 IPCC GL Table 2.6
- **0.55** for modified natural forest, as it is the value for secondary tropical forest (slash and burn) according to 2006 IPCC GL Table 2.6

G_{ef} emission factor, g kg-1 dry matter burnt. This is equal to:

- **6.8** for CH4 as it is the value for tropical forest according to 2006 IPCC GL Table 2.6
- **0.2** for N2O as it is the value for tropical forest according to 2006 IPCC GL Table 2.6

In order to convert these GHG emissions to tCO2e, GHG emissions from CH4 and N2O are multiplied by the Global Warming Potential for both gases (GWP), so the equation would be as follows:

$$L_{fire,t} = A(j,i) x AGB_{Before,j} x C_f x (G_{ef_{ch4}} x GWP_{CH4} + G_{ef_{N2O}} x GWP_{N2O}) x 10^{-3}$$ **Equation 16**

Where :

GWP_{CH4} Global Warming Potential of CH4, = 28

GWP_{N2O} Global Warming Potential of N2O, = 265

Values from the last AR5 are used as recommended, all the numbers updated accordingly

Global Warming Potential (GWP) of CH4 and N2O value can be found on the link .
https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf .

Reducing Emissions from Degradation / Forest Land remaining Forest Land

Following the recommendations set in chapter 2.5.1.2 of the GFOI Methods Guidance Document, GHG emissions from degradation will be estimated by taking "account of long-term reductions of carbon densities due to transitions between forest strata and sub-strata, and within the strata and substrata affected by human activity (i.e. MNF and planted forests)". In essence this means, by multiplying activity data of transition between different types of forest by the difference in average carbon stocks.

Considering equation 2.16 of the 2006 IPCC GL for estimating $\Delta C_{CONVERSION}$ and considering 2.8 b for the estimation of carbon stocks, the change of biomass stocks could be expressed with the following equation.

$$\Delta C_{B,t} = \sum_{j,i} \left(AGB_{Before,j} x(1+R_j) - AGB_{After,i} x(1+R_i)\right) x\ CF\ x \frac{44}{12} \times A(j,i)$$ **Equation 17**

Where:

$A(j,i)$ Area of forest converted from primary forest to modified natural forest – disturbed forest or to plantation during the reference period, in hectare per year. The description of this parameter may be found further below**.**This could be the following conversions:

- **Primary forest to Disturbed Forest (D-PF DF);**
- **Primary forest to Agroforestry (D-PF AF);**
- **Primary forest to Plantations (D-PF PL);**
- **Disturbed Forest to Agroforestry (D-DF AF)**
- **Disturbed Forest to Plantations (D-DF PL)**

$AGB_{Before,j}$ Above-ground biomass of forest type j before conversion, in ton of dry matter per ha. This is the above-ground biomass of **Primary forest (PF)** or **Disturbed Forest (DF).** The description of this parameter may be found further below.

Rj ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in ton d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to:

- **0.24** is the default for tropical moist deciduous forest, >125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for primary forest and disturbed forest.

$AGB_{After,i}$ Above-ground biomass of non-forest type I after conversion, in tons dry matter per ha. This is the above-ground of **Disturbed Forest (DF)** or **Agroforestry (AF)**. In the case of **Plantation (PL)** this is assumed to be zero so as to comply with the requirements on Safeguards of the Cancun agreements. The description of this parameter may be found further below.

R_i ratio of below-ground biomass to above-ground biomass for a specific vegetation type i, in ton d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to:

- **0.24** is the default for tropical moist deciduous forest, >125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for primary forest and disturbed forest.
- **0.2** is the default for tropical moist deciduous forest when above-ground biomass is <125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for Agroforestry.

CF Carbon fraction of dry matter in tC per ton dry matter. The value used is:

- **0.47** is the default for tropical forest as per IPCC AFOLU guidelines 2006, table 4.3.

$44/12$ Conversion of C to CO2

Enhancement of carbon stocks in new forests / Land Use Change from non-Forest Land to Forest

Following the recommendations set in chapter 3.1.4 of the GFOI Methods Guidance Document, enhancement of carbon stocks in afforestation/reforestation will be estimated by multiplying the activity data by the yield tables or growth curves in the generation of changes in carbon density through time on afforested/reforested lands. Since there are no such tables in Madagascar in regenerated forest, it will be assumed that afforested/reforested lands take 15 years to reach the status of secondary forest. This is seen as a better option than using averages, which is the alternative proposed in Chapter 3.14 of GFOI which would be a source of bias.

Therefore, the annual change in carbon stocks would be estimated as follows:

$$\Delta C_{B,t} = \sum_{j,i} \frac{\left(AGB_{Before,i} - AGB_{After,j}\right)}{\text{Years growth}} x(1+R) x\ CF\ x \frac{44}{12} \times A(i,j)$$ **Equation 18**

Where:

ΔC_B Change of total carbon stocks during the monitoring period, in tC per hectare, per year.

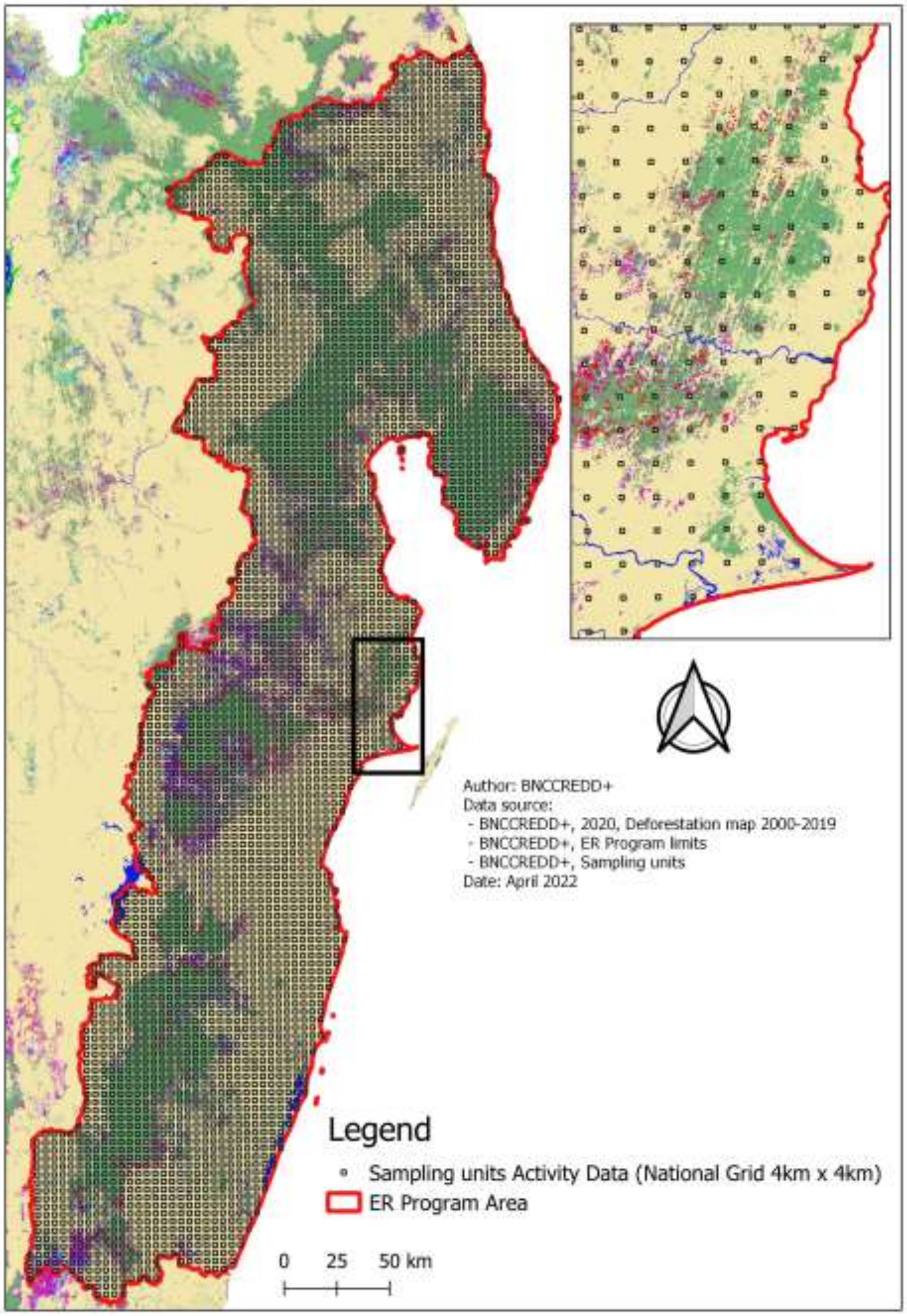
$A(j,i)$ Annual conversion from non-Forest Land use i to forest type j (planted forest or modified natural forest). The description of this parameter may be found further below**.** Area of forest converted

	from non-forest to forest during the reference period, in hectare per year. In this case, it would be : • **Non-forest to Secondary Forest** • **Non-Forest to forestry**
$AGB_{Before,i}$	Above-ground biomass of non-forest type i before conversion, in tons dry matter per ha. In this case, it would be the above-ground biomass of **non-forest (NF)**. The description of this parameter may be found in **Section 3.2.**
$AGB_{After,j}$	Above-ground biomass of forest type j after conversion, in ton of dry matter per ha. The description of this parameter may be found in **Section 3.1.** In this case, it would be the above-ground biomass of : • **Secondary Forest (SF);** • **Agroforestry (AF);** • **Plantations (PL);**
R	ratio of below-ground biomass to above-ground biomass for a specific vegetation type i, in ton d.m. below-ground biomass (ton d.m. above-ground biomass)$^{-1}$. This is equal to: • **0.2** is the default for tropical moist deciduous forest when above-ground biomass is <125 t.d.m./ha according to 2006 IPCC GL, TABLE 4.4, Volume 4, Chapter 4. This is the case for Secondary Forest, Agroforestry and non-forest. • **3.35** is the root shoot ratio of Eucalyptus plantations according to RAZAKAMANARIVO et al. (2013). This is the case for Plantations.
Years growth	Number of years to transit from Non-forest to forest. The value used is: • **15** years is assumed as the secondary forest is assumed to have 20 years in average and the savouka jeune or non-forest represents a secondary vegetation of 5 years in average.
CF	Carbon fraction of dry matter in tC per ton dry matter. The value used is: • **0.47** is the default for tropical forest as per IPCC AFOLU guidelines 2006, table 4.3.
44/12	Conversion of C to CO2

Activity data and emission factors used for calculating the average annual historical emissions over the Reference period

Table 21: Activity data and emission factors used to calculate the average annual historical emissions in relation to the Reference period

Parameter :	$A(j,i)\ A(i,j)$
Description :	*Annual conversion from forest type j (primary forest, modified natural forest), to non-Forest Land uses i (Non-Forest) in period 2006-2015* *Annual conversion from forest type j (primary forest), to Forest type i (modified natural forest or plantations)* *Annual conversion from non-Forest Land use i to forest type j (planted forest or modified natural forest) in period 2006-2015*
Data unit :	ha/year
Source of data and description of measurement/ calculation methods and procedures applied:	As indicated previously, design-based inference has been used to estimate the activity data. Sampling design Estimator: Simple random estimator of a proportion Stratification: No stratification. Calculation of the sample size: No calculation since it was based on the data from the national grid. Drawing of samples For the monitoring of the emission reduction program (and even the initiatives), the sampling is stratified because the monitoring period is short (1-3 years). Systematic sampling is used for the baseline and also longer periods (5-10 years). The points of a national grid with a step of 4 km are clipped according to the delimitation of the PRE AA Program area and 4,308 points are selected.



Location of sampling units

Response design

Spatial assessment unit:

The spatial assessment unit is a squared area of 70 meter of side which contains 25 points inside and which is centered on the random point selected from the sampling frame. Considering the acceptable geolocation error of Landsat imagery is 30 meters, this spatial assessment unit would be justified.

However, in terms of spatial support the information beyond the limits of the plot were used to assess whether one object within the assessment unit would comply with the minimum mapping unit.

Assessment or sampling unit

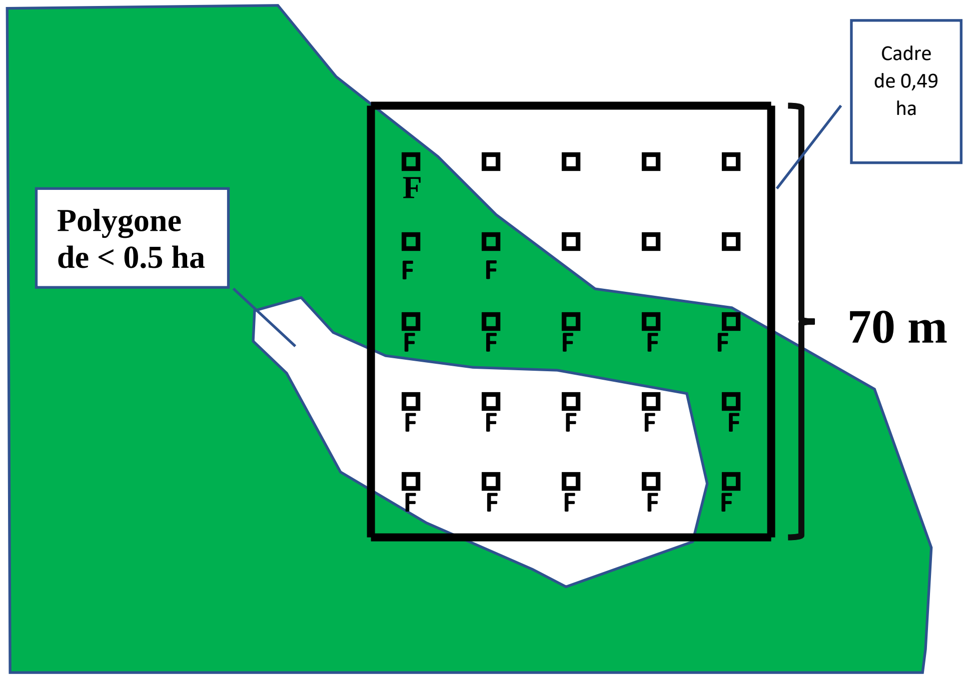
Source of the reference data:
The reference data in this case will be collected through visual interpretation of all satellite imagery available to the country. This includes:

- Planet basemap : from 2016 to 2021, with 3m high resolution imagery available through the NICFI grants to tropical countries. Planet data has more recent imagery compared to other high resolution satellite images.
- Google Earth and Bing: All high and very high-resolution imagery accessible through Google Earth and Bing. The spatial coverage of very high-resolution imagery in the ER program area is relatively high, with many areas with coverage from 2005 to 2015.
- Aster: Resolution of 15 meters from 2000 to 2009
- Landsat 5 TM and 7 ETM+: Available through google earth engine.
- Landsat 8 OLI: Available through google earth engine for 2013-2017.
- Sentinel 2A MSI: Available through google earth engine for 2015-2017.

It is considered that these are reference data as most of the interpretations will be based on direct interpretation of higher resolution imagery for different periods which provides the necessary temporal contextual information.

Reference labelling protocol

- Forest/Non Forest classification: In order to attribute the condition of forest to the sample, the interpreter would evaluate how many points of the grid would fall over forest (a differentiated object that has at least 0,5 ha in area and has 30% of tree canopy cover). If at least 13 points (>50% of points) fall in forest, the point would be classified as forest, otherwise as non-forest. This method ensures that there is no overrepresentation of forest, which happens with hierarchical classification systems. In the example below, we can see that although eight points are included in a polygon without a tree, this polygon is smaller than 0.5 ha, and it is included in another polygon which is more than 0.5 ha. In this case, the sampling unit is classified as forest.



Example of interpretation of sampling unit

- Forest types: If the sample is classified as forest, the sample would then by attributed to one of the 5 forest types based on the majority class present:
  - Primary forest
  - Modified Natural forest – Disturbed forest
  - Modified Natural forest – Agroforestry
  - Modified Natural forest – Secondary forest
  - Plantation – Plantation for wood
- Interpretation has been based on a protocol which be found in the website of BNCCREDD+ (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-linterpretation-des-donnees#)
- QA/QC: A number of QA/QC procedures have been applied:

The results of the interpretation are the following:

Analysis design
The average proportion of the variable of interest in the reference period will be estimated through the simple random estimator of the mean.

In order to convert the proportions to areas, the average proportion is multiplied by the total area of the region of interest of 6,980,308 ha.

Estimate of proportions per class

Activity	Type	Stratified estimate (proportion)	Area estimate (ha)
Deforestation	Dense humid forest	0.004	27,502
	Degraded humid foret	0.032	225,185
	Secondary forest	0.00023	1,605
	Agroforestry	0.00023	1,605
	Plantations	0.0000	0
Enhancement	Secondary forest	0.001	8,097
	Agroforestry	0.0000	0
	Plantations	0.0000	0
Degradation	PF to Disturbed forest	0.017	118,246
	PF to Agroforestry	0.0000	0
	PF to Plantations	0.0000	0
	DF to Agroforestry	0.0000	0
	DF to Plantations	0.0000	0

In order to express the proportion of deforestation or afforestation/reforestation in annual basis, the sample estimate is divided by the duration of the reference period (i.e. 10 years).

Estimate of activity data per class

Activity	Type	Area (ha/year)
Deforestation	Dense humid forest	2750.24
	Degraded humid forest	22518.47
	Secondary forest	160.55
	Agroforestry	160.55
	Plantations	0
Degradation	PF to Disturbed forest	11824.64
	PF to Agroforestry	0
	PF to Plantations	0
	DF to Agroforestry	0
	DF to Plantations	0
Enhancement	Secondary forest	809.72
	Agroforestry	0
	Plantations	0

More information is provided in the spreadsheet "MADA_CalculRE_v00_20211109_update_for_ER_Report_version_6" and in https://drive.google.com/file/d/1QQtpS_4RpcF9rKIARd-eBE0YMeRa5H4C

Value applied :

Activity	**Type**	**Area (ha/year)**
Deforestation	Dense humid forest	2750.24

		Degraded humid forest	22518.47
		Secondary forest	160.55
		Agroforestry	160.55
		Plantations	0
	Degradation	PF to Disturbed forest	11824.64
		PF to Agroforestry	0
		PF to Plantations	0
		DF to Agroforestry	0
		DF to Plantations	0
	Enhancement	Secondary forest	809.72
		Agroforestry	0
		Plantations	0
QA/QC procedures applied:	• QC procedures in this case consist in the establishment of a Standard Operating Procedure (SOP) for the interpretation of the samples and the application of training procedures in order to ensure the correct implementation of SOPs. The SOPs designed prior to the data collection may be found in the website of BNCCREDD+ (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-collecte-des-donnees#) • The forms of Collect Earth were also designed to implement validation rules that would avoid any consistency errors. Since validation rules could not avoid all possible inconsistency errors, the results of sampling units collected one day were reviewed by a different interpreter to check consistency. • Expert interpreters were used, sufficiently trained, with a specific SOP for interpretation. • Moreover, the interpreters indicate whether the quality of interpretation is high or low, so this serves to filter out those points that are of low quality in the interpretation. All sampling units labelled as low-confidence are re-assessed by and expert interpreter. • When collecting activity data in the Collect Earth tool: In general, once you fill in the information on a plot, you have to check the information included. Especially if the assigned change of cover and the classes of the two dates studied are logical. You have to have reasoning and correspondence. An operator other than the one who performed the data collection retests a random sample of 20 percent of the total number of samples during Quality Assurance. For quality control, 5% of the added samples of all change classes and those with low confidence are reanalyzed by the group (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-collecte-des-donnees#). • During data analysis: The Laboratory and Methodology Manager, in coordination with the analysts, checks that the calculations comply with SOP number 4 on data analysis, including the script used for the calculations. Then they cross-check the estimates with previously reported estimates for the same classes. Estimates are further cross-checked and compared to estimates reported by other sources (e.g. Global Forest Resources Assessment, National Greenhouse Gas Inventory, UNFCCC reports, Global Forest Watch…) (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-lanalyse-des-donnees#).		

<table>
<tr><td rowspan="2">Uncertainty associated with this parameter:</td><td>

Activity	**Type**	**Standard error (proportion)**	**90% confidence – Relative margin of error**
Deforestation	Dense humid forest	0.001	40%
	Degraded humid forest	0.003	14%
	Secondary forest	0.00023	165%
	Agroforestry	0.00023	165%
	Plantations	-	
Enhancement	Secondary forest	0.001	72%
	Agroforestry	-	
	Plantations	-	
Degradation	PF to Disturbed forest	0.002	19%
	PF to Agroforestry		
	PF to Plantations	-	
	DF to Agroforestry	-	
	DF to Plantations	-	

</td></tr>
</table>

Any comment :	

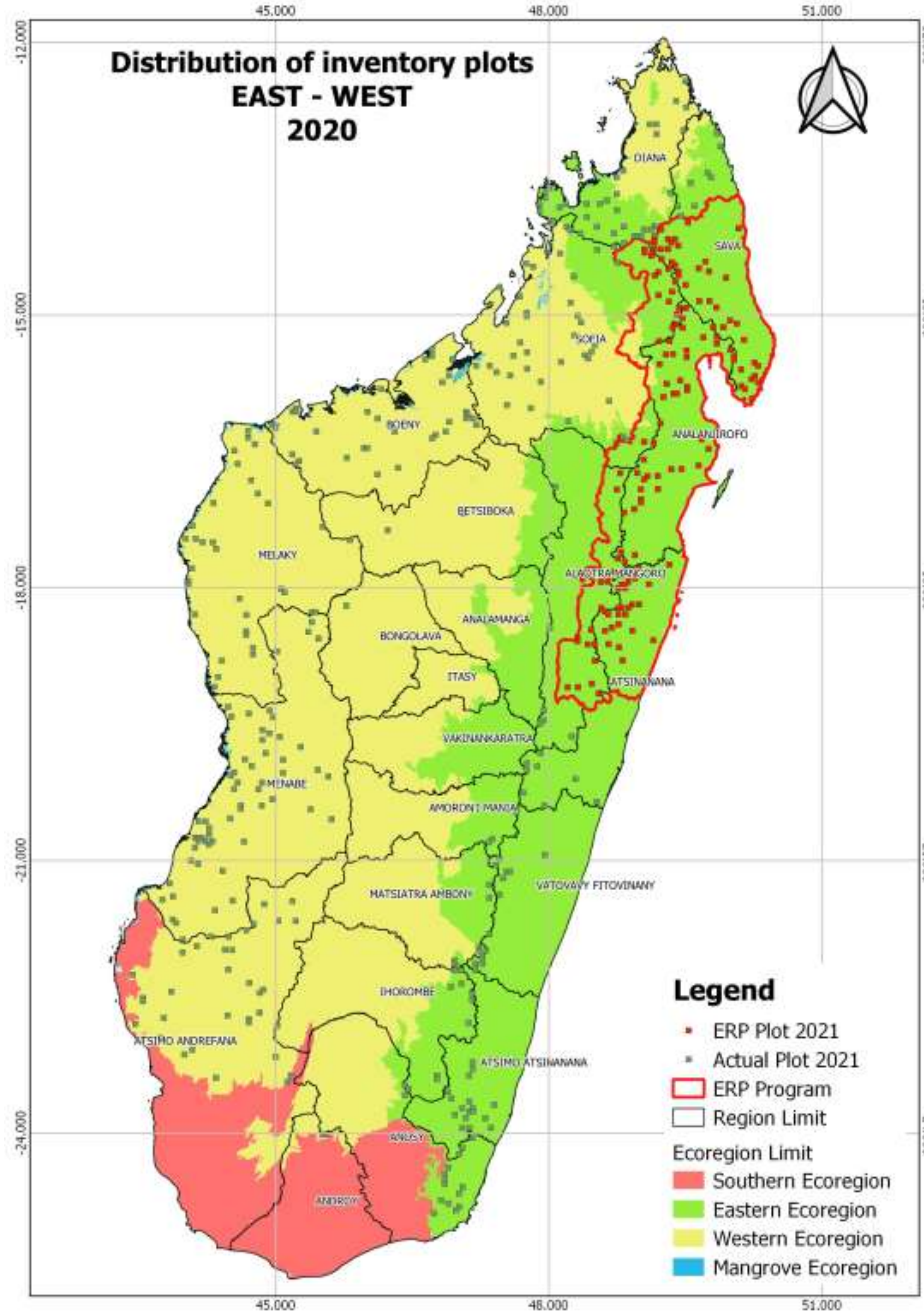
Emission factors

Parameter :	$\mathrm{AGB}_{\mathrm{Before,j}}$ $\mathrm{AGB}_{\mathrm{After,j}}$ $\mathrm{AGB}_{\mathrm{Before,j}}$ $\mathrm{AGB}_{\mathrm{After,j}}$ -
Description :	Aboveground biomass of forest type j before conversion, in tonne of dry matter per ha; Aboveground biomass of forest type i after conversion, in tonnes dry matter per ha; Aboveground biomass of forest type j before conversion, in tonne of dry matter per ha; Aboveground biomass of forest type i after conversion, in tonnes dry matter per ha;
Data unit :	tdm/ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The source is primarily three different inventories or sources: • PERR-FH inventory, 2014: As part of the PERR-FH project, intact forests were measured in 2014 using a total of 189 plots located within the Ecoregion of the Eastern Humid Forests. • DVRF inventory, 2016: Since the national inventory did not cover secondary formations, an inventory was conducted in 2016 by DVRF targeting the following secondary forests: Agroforestry; Ravenala mixte; Ravenala; Single layer; and Savoka vieux. A total of 262 plots were measured. From all these formations, the single layer represents a more mature formation, which usually is the result of degradation of primary forest or old secondary forest. In this case, plots were located close to the forest boundary around 100-150 metres in distance. The other formations are secondary formations generally created after slash of primary forest. These formations have a similar stock of aboveground biomass, so Ravenala, Ravenala mixte and Savoka vieux has been decided to be merged into the secondary forest class. • DRGPF inventory, 2020 : this inventory concerns all the forests in the eastern areas of Madagascar. This is the updating of inventory data according to the national 4kmx4km grid.

272 plots were inventoried. Three classes were considered: de.nse humid forest, degraded humid forest and secondary forest.

Estimates of AGB according to inventory DRGPF, 2020

Stratum	**AGB (tdm/ha)**	**Relative margin of error at 90% of confidence level**
Dense humide Forest	202.63	7%
Degraded humide Forest	186.00	11%
Secondary Forest	91.11	30%



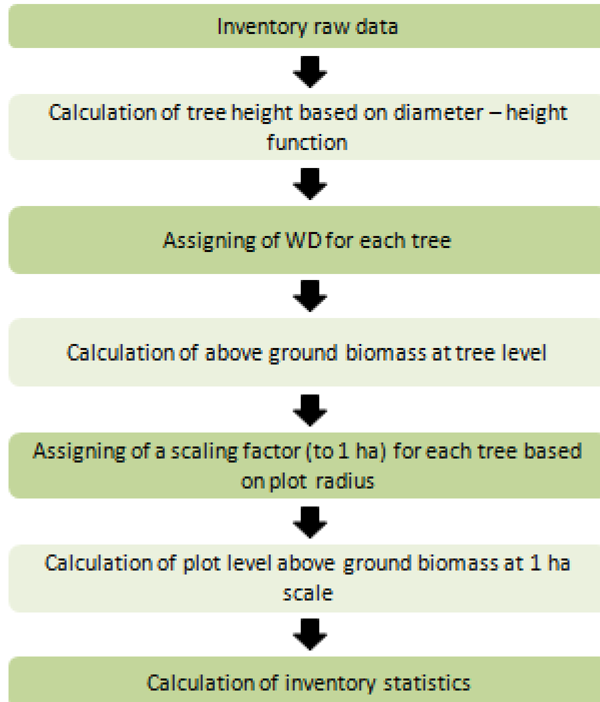
Distrubution of forest inventory plots

The following sections include a description on how these data were processed and the above values were derived.

A/ Processing Workflow

Inventory data was processed as follows.

Inventory data processing workflow



Inventory data used to calculate ground biomass was selected as follows:

- (Woody) trees of dbh ≥ 5 cm;
- All of the Palm (*Ravenala madagascariensis* and *Dypsis sp*.).

B/ Height calculation

Allometric equations used to calculate tree biomass usually have for variable the height (total height in the case of trees, total height or trunk height in the case of the palms. The height not having been systematically measured for all trees, equations were built in order to complete the missing data.

The tree height data of trees collected in the field data was used to develop a height diameter relation based on a function proposed by Chave et al. (2014). According to the field stratum, several height-diameter relations have been established. The table below shows the relations that were developed, the corresponding stratum, the number of trees used to build this relation, as well as the relative error.

For the particular case of the Palm, specific relationships were also established in order to complete the data in the rare case where the height was not measured:

- Either to measure the total height (in the case of the *Ravenala madagascariensis*), from the height of the trunk or from diameter at height of collar (DHC) depending on available data
- Or to measure the height of the trunk (in the case of the *Dypsis sp*.), from the total height.

Relations used for calculating heights

Strata	**N°**	**Equation**	**Number of trees**

Primary Forests –PERR-FH 2014 Inventory	1	$\ln(H) = -0.07511*\ln(D)^2 + 0.988*\ln(D) + 0.267$	1,270
« Savoka vieux » or « Agroforestry » strata of the 2016 inventory	2	$\ln(H) = -0.0709*\ln(D)^2 + 0.9257*\ln(D) + 0.371$	1,365
« Mix Ravenala » strata of the 2016 inventory	3	$\ln(H) = -0.106*\ln(D)^2 + 1.1305*\ln(D) + 0.0097$	499
Palm: Dypsis sp.	4	$H_{stip} = 0.3772*H + 1.7639$	25
Palm: Ravenala madagascariensis	5	$\ln(H) = -0.0699*\ln(DHC)^2 + 0.9956*\ln(DHC) – 0.8902$	1,010
	6	$H = 0.9391*H_{stip} + 5.7537$	493
Humide Forest DRGPF 2020 Inventory	7	$H = 0,0362\ (D)2 + 1,0742\ D + 4,86$	18,959

Where:

H: total height, in m

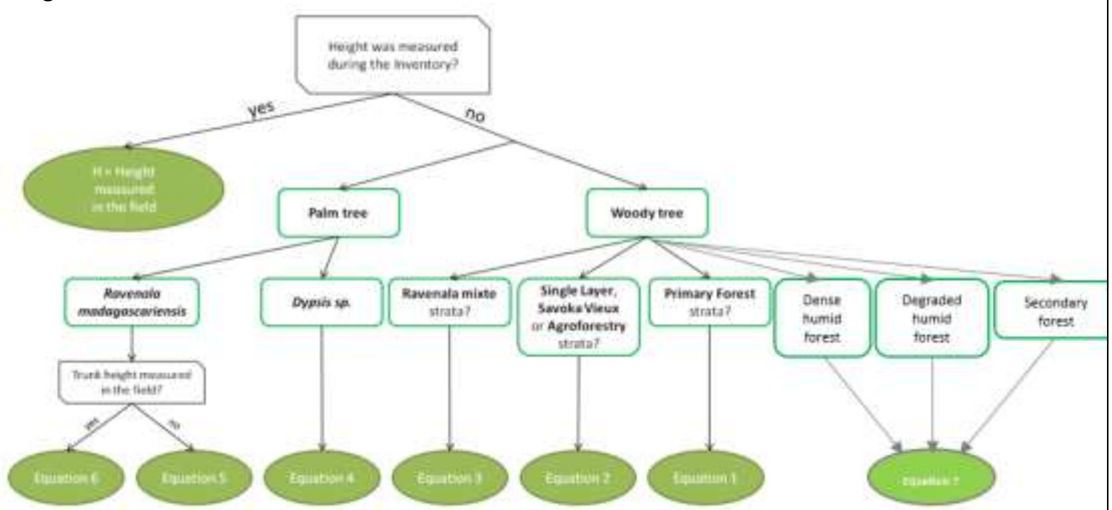
D: diameter at breast height, in cm

DHC: diameter at collar height (Palm trees) in cm

H_{stip}: height of the trunk (Palm trees), in m

Later in the calculations, this calculated height by tree has been used only for trees which were not measured in height on the ground: in other cases, it is the measured height that was used.

The choice of the relation to be used to calculate the height is illustrated by the decision tree shown in Figure below.

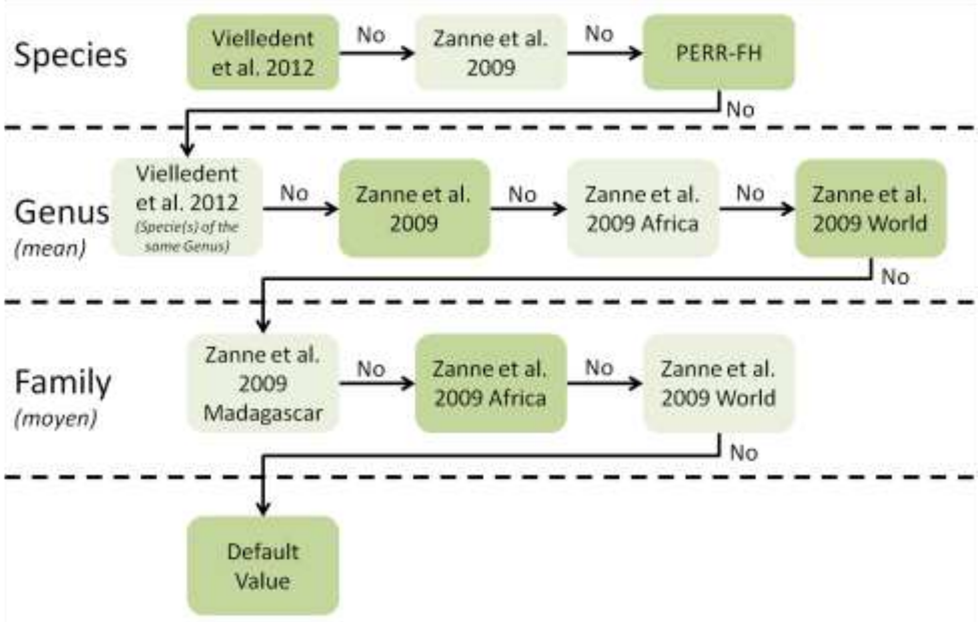


Decision tree to calculate height

C/ Wood density assignation

For the evaluation of the biomass of sites/species, the search for specific, generic and family-level densities was essential. For this, the databases of Vielledent et al (2012), Zane et al (2009), Zane et al (2009) Madagascar, Perr-FH and LRA (2021) were used.

The figure below was respected during the search for specific densities.



Decision tree for assigning WD

Wood densities were assigned based on the following 3 main databases:

4. A wood density database compiled by Vielliedent et al. (2012) for research related to allometric equations
5. The global wood density database compiled by Zanne et al. 2009
6. The PERR-FH wood density database compiled by the PERR-FH project for the purpose of the PERR-FH inventory

In the order of the above appearance, these 3 databases were searched for a WD value at the species level. If no WD value was found or only the genus of the tree was known, then WD values were assigned based on the genus in the following order of priority:

9 WD VALUE FROM A SPECIES OF THE SAME GENUS FROM THE DATABASE OF VIEILLEDENT ET AL. (2012)

10 MEAN WD ACROSS THE GENUS FOR SPECIES FOUND IN MADAGASCAR FROM THE DATABASE OF ZANNE ET AL. 2009

11 MEAN WD ACROSS THE GENUS FOR SPECIES FOUND IN AFRICA FROM THE DATABASE OF ZANNE ET AL. 2009

12 MEAN WD ACROSS THE GENUS FROM THE ENTIRE DATABASE OF ZANNE ET AL. 2009

In cases where only a single species of the same genus was found, the WD of this species was assigned.

If no WD value was available at the genus level or only the family of the tree was known, then WD values were assigned based on the family in the following priority order:

3. Mean WD across the family for species found in Madagascar from the database of Zanne et al. 2009
4. Mean WD across the family for species found in Africa from the database of Zanne et al. 2009
5. Mean WD across the family from the entire database of Zanne et al. 2009

Finally, if no wood density could be assigned through the above process either because no WD data was available or the tree could not be identified then a conservative WD default value of 0.5 was assigned (this value was chosen because it corresponds to the default value used in the PERR-FH project).

D/ Calculation of AGB at tree level

The tree level biomass was calculated based on the following allometric equation.

Allometric equations used to calculate ground biomass

STRATA OR SPECIES		EQUATION	SOURCE
Trees (woody)	Humid forests (DRGPF 2020, inventory)	$\ln(AGB_{est}) = -1.103+1.994*LN(D)+0.317*LN(H_{tot})+1.303*LN(\rho))$	Vieilledent et al. (2012)
	Primary forests (PERR-FH 2014 inventory), modified forests ('Old Savoka' or 'Agroforestry' strata of the 2016 Inventory)	$\ln(AGB_{est}) = -1.948+1.969*LN(D)+0.66*LN(H_{tot})+0.828*LN(\rho))$	Vieilledent et al. (2012)
	(woody) trees of modified forests (« Ravenala mixte » strata of the inventory)	$\ln(AGB_{est}) = -1.56 + 1.912*\ln(D) + 0.471*\ln(H_{tot}) + 0.732*\ln(\rho)$	Ramananantoandro et al., 2017
Palms	*Ravenala madagascariensis*	$\ln(AGB_{est}) = -5.08 + 5.654*\ln(H_{tot}) - 0.772*\ln(H_{tot})^2$	Ramananantoandro et al., 2017
	Dypsis sp.	By default, the allometric equation that has been used is that of the *Chrysophylla sp* species as this was the equation which gave better results: $AGB_{est} = 0.182 + 0.498 *H_{stip} + 0.049*H_{stip}^2$	IPCC 2003 LULUCF GPG, Annex 4A.2 (Delaney et al. 1999 ; Brown et al. 2001)

With:

AGB_{est}: Estimated *Above-Ground Biomass* in tdm

ρ: Wood density

D:	Diameter at Breast Height (DBH), in m
H_{tot}:	Total height of the tree or palm (for the palm, including fronds)
H_{stip}:	Height of the trunk (stem height of the Palm, without considering the fronds)

E/ Calculation of AGB at plot level

A scaling factor was applied to scale the values calculated at the individual tree level to 1ha. Since each plot consists of 04 subplots, different scaling factors were assigned based on the DBH of each tree. Table 5 shows the scaling factors for the fixed-size subplots.

Plots description

DBH [cm]	Sides	Surface (Side*Side) in m²	Scaling factor	DBH [cm] Ecoregion	
				Est	Ouest
Small trees	10	100	100	5 <DBH≤15	5< DBH ≤10
Medium trees	20	400	25	15< DBH ≤30	10< DBH≤20
Large trees	50	2500	4	>=30	>=20
Regenerations	(1*1)*4	4	2,500	<5	<5

DBH (cm), total height (m), dead tree quality were recorded.

F/ Inference

****Arithmetic mean***

Sampling does not give real values. The results of the sampling are always estimates of the total population studied. Therefore, the average was calculated using the following formula.

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

(13)

Où yi est la valeur du paramètre pour le $i^{ème}$ échantillon et n est le nombre total d'échantillons relevés. Le calcul de la moyenne arithmétique est automatisé sur le tableur Excel.

The average was used to know the average value of total height, bole height and diameter at breast height at 1.30m from the ground. The analysis of the value of land area, volume and biomass was also done using the arithmetic mean. Finally, it was used to know the general trend of the standing trees or the formation in general in the areas of inventories.

Estimates of above-ground biomass per forest type

Forest type	AGB (tdm/ha)	Number of samples
Dense humid forest	202.63	155
Degraded humid forest	186.00	85
Secondary forest	91.11	21

More information is provided in the spreadsheet ¨MADA_Biomasse_aerienne_et_Morte_20220410_v01¨ which may be found in the link https://drive.google.com/file/d/1Bgm0DqFAFN7zIeeOrGHhYgDaUIycvMa1

Value applied:

Forest type	Estimate (tdm/ha)
Dense Humid forest	202.63
Degraded humid forest	186.00
Secondary Forest	91.11
Agroforesterie	87.87
Plantation	29.55

QA/QC procedures applied:

Uncertainty associated with this parameter:

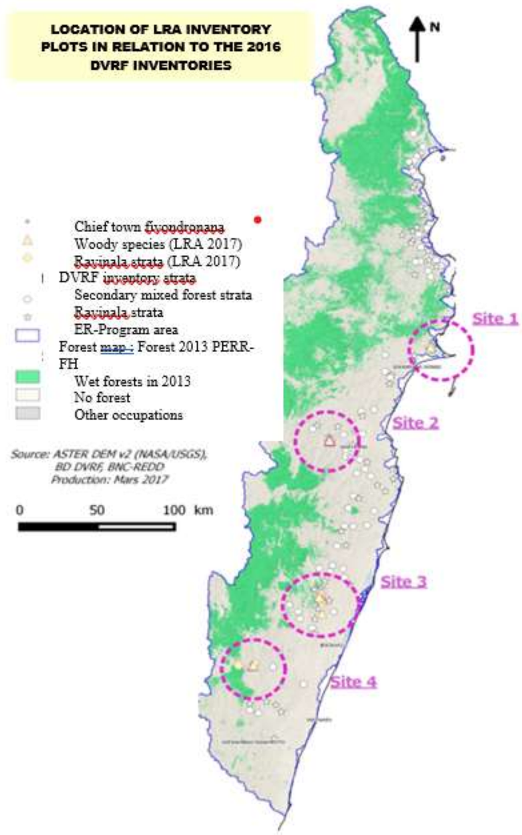
Class	BA (tdm/ha)	Stdev	Number of samples	SE	Relative margin of error at 90%
Dense Humid forest	202.63	99.59	155	8.00	7%
Degraded humid forest	186.00	111.90	85	12.14	11%
Secondary Forest	91.11	72.79	21	15.88	30%
Agroforesterie	87.87	40.45	28	7.64	15%
Plantation	29.55			6.25	35%

Any comment:

Parameter:	$AGB_{After,i}$ $AGB_{Before,i}$ *(non-forest)*
Description :	Aboveground biomass of non-forest type j before conversion, in tonne of dry matter per ha Aboveground biomass of non-forest type i after conversion, in tonnes dry matter per ha;
Data unit:	t d.m./ha
Source of data or description of the method for developing the data including the spatial level of	This are sourced from a destructive sampling of Savouka Jeune secondary formations conducted as part of the Laboratoire de Recherches Appliqués in 2016-2017. These formations are the precursors of Savouka vieux, revenala mix and agroforestry formations. ***A/ Sampling design*** The samples were located in four different areas, located in the Centre and the South of the ER program area. These locations are part of the regions of Analanjirofo, Atsinanana and Alaotra Mangoro. Its general characteristics are the following : • Site 1 (Axe Soanierana Ivongo): centre of the ER program and below 200 m of altitude;

the data (local, regional, national, international) :

- Site 2 (Axe Vavatenina): centre of the ER program and at least 400 m of altitude; ;
- Site 3 (Axe Brickaville): south of the. ER program and below 400 m of altitude;
- Site 4 (Axe Andasibe): south of the ER program and above 400 m of altitude.



Location of plots for estimation of biomass in non-forest

In each of the sites a number of 1 m^2 were established and they were established at different locations within watersheds in order to understand the impact of this in the aboveground biomass. Moreover, the plots within each of the slopes were located on Savoka jeune with different ages ranging from 4 to 10 years in order to understand the variability of Savouka Jeune with age. A total of 292 plots were established.

Number of sampling units per site for the estimation of biomass in Savouka Jeune

Topographic position	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**TOTAL**
C1 : low slope	19	27	21	22	292
C2 : mid-slope	23	26	24	24	
C3 : high slope	19	34	27	26	
TOTAL per site	61	87	72	72	292

<table>
<tr><td></td><td>

B/ Measurement

Within these plots, a destructive measurement of herbaceous vegetation and woody vegetation was made. The samples were then taken to laboratory and the samples were dried at a temperature of 70°C for the leaves and the herbaceous vegetation and 103°C for the shrubs until constant weight between 24 hour intervals. In general the drying process has taken 3 days in the case of leaves and grasses, and the woody biomass has taken 5 days.

Picture of bags with destructive samples

The anhydrous mass of the shrubs and grasses has been measured with a balance with 0.01 g accuracy.

C/ Statistical analysis

Different statistical analysis with packages was done on the results.

The average estimate of Aboveground Biomass is estimated through the random estimator of the mean ($\hat{\mu}$):

$$\hat{\mu} = \frac{1}{n}\sum_{k=1}^{n} y_k$$

Where:

- y_k is the k sample estimate given by the biomass estimated per plot as described above. This is the biomass per sampling unit estimated above.
- n is the number of samples
- For the ensemble of the four sites, the biomass factor for Savoka jeunes is of 11.96 ±6.5 t/ha.

</td></tr>
<tr><td>Value applied:</td><td>11.96</td></tr>
<tr><td>QA/QC procedures applied:</td><td>Inventory quality control: technical supervision by DRGPF and BNCCREDD+ supervisors and strategic supervision by MEDD staff, verification of inventory sheets and databases.</td></tr>
</table>

<table>
<tr><td>Uncertainty associated with this parameter:</td><td>The main uncertainty is the sampling uncertainty and the representativeness of the data. See Chapter 12.
The sampling error is estimated through the following formula.
$$\widehat{Standard\ error}(\hat{\mu}) = \frac{1}{\sqrt{n} \times (n-1)} \times \sum_{k=1}^{n} (y_k - \hat{\mu})^2$$
Where:
• y_k is the k sample estimate given by the biomass estimated per plot as described above. This is the biomass per sampling unit estimated above;
• $\hat{\mu}$ the random estimator of the mean;
• n is the number of samples.

The result is multiplied by the t-student value for the 90% confidence level in order to estimate the confidence interval. The margin of error is the half width of the confidence interval divided by the average estimate.

Estimates of AGB in non-forest
<table><tr><th>Class</th><th>BA (tdm/ha)</th><th>Stdev</th><th>Number of samples</th><th>SE</th><th>Relative margin of error at 90%</th></tr><tr><td>Non Forest</td><td>11.96</td><td></td><td>120</td><td>3.28</td><td>46%</td></tr></table></td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

<table>
<tr><td>Parameter:</td><td>C_O</td></tr>
<tr><td>Description :</td><td>dead wood/litter stock, under the old land-use category, tonnes C ha-1.</td></tr>
<tr><td>Data unit:</td><td>tC/ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local,. regional, national, international):</td><td>The same calculation procedures as the aboveground biomass were followed, but only with the trees that were labelled in the field as dead trees. This resulted in the following:

Estimates of dead wood per forest type
<table><tr><th>Forest type</th><th>DW (tdm/ha)</th></tr><tr><td>Dense humid forest</td><td>0.08</td></tr><tr><td>Degraded humid forest</td><td>0.09</td></tr><tr><td>Secondary forest</td><td>0.06</td></tr></table>
These values were then multiplied by 0.47 in order to provide the carbon stocks.</td></tr>
<tr><td>Value applied:</td><td><table><tr><th>Forest type</th><th>Value</th></tr></table></td></tr>
</table>

Official Use

	Dense humid forest	0.08
	Degraded humid forest	0.09
	Secondary forest	0.06
QA/QC procedures applied:	Inventory quality control: technical supervision by DRGPF and BNCCREDD+ supervisors and strategic supervision by MEDD staff, verification of inventory sheets and databases.	

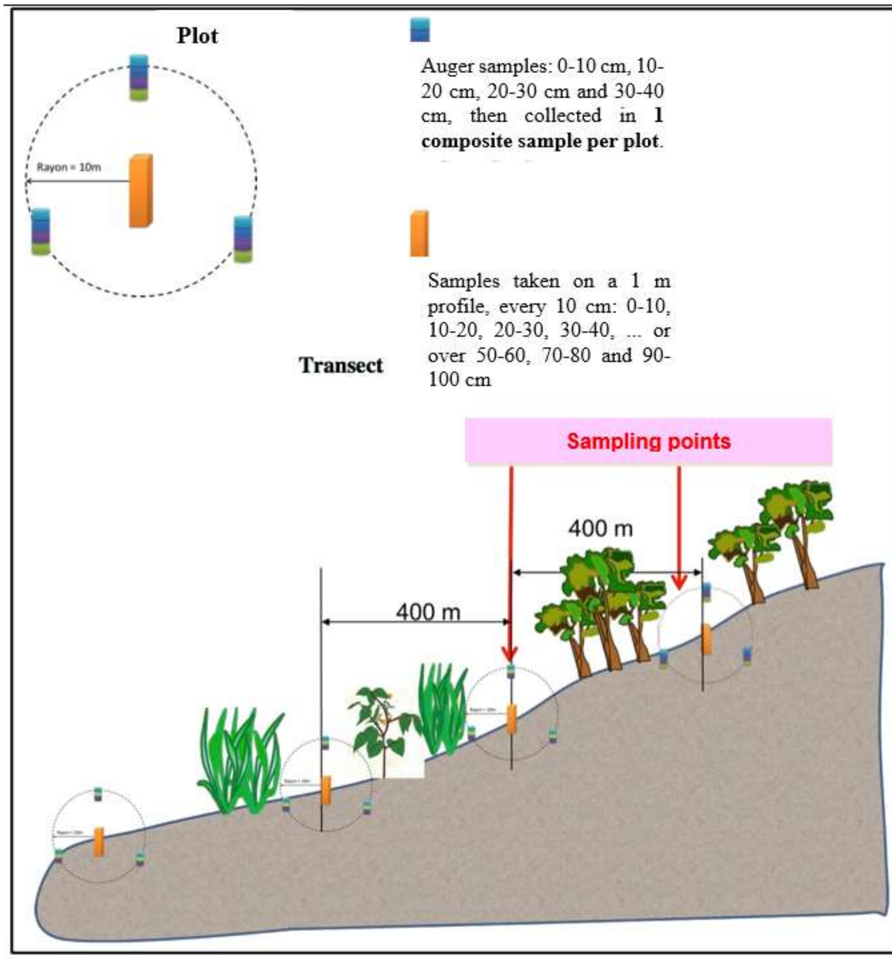
Uncertainty associated with this parameter:

Class	**DW (tdm/ha)**	**SE**	**Relative margin of error at 90%**
Dense humid forest	0.08	0.01	19%
Degraded humid forest	0.09	0.01	21%
Secondary forest	0.06	0.02	67%

Any comment:

Parameter:	$SOC_{Before,j}$ $SOC_{After,i}$
Description :	Soil Organic Carbon at 30 cm depth of forest type j before conversion, in tonne of carbon per ha and Soil Organic Carbon at 30 cm depth of non-forest type j after conversion, in tonne of carbon per ha.
Data unit:	tC/ha
Source of data or description of the method for developing the data including the spatial level of the data (local,. regional, national, international):	The data of soil estimates are based on a specific inventory conducted in the Eastern Humid Ecoregion as part of the PERR-FH (https://redd.unfccc.int/files/20180528_frel_mada_modified.pdf) ***A/ Sampling plan*** The inventory consistent in sampling in four different regions within the ecoregion, where 5 different chrono sequences were established.

	 *Location of soil sampling units* The chronosequences were established so as to understand the changes in carbon stocks from Forests to the Tavy system, and to understand these changes across time as shown in the following figure.



View of the chrono sequences sampling for soil organic carbon

A total of 200 samples were collected, 75 in forest and 125 in non-forests, 50 in each of the four regions identified.

Sample size for the estimation of SOC

Class	**Forest**	**Non-Forest**	**Total**
Ambanja	26	24	50
Tamatave Est	22	28	50
Moramanga Sud	11	39	50
Ivohibe	16	34	50
Total	75	125	200

B/ Measurement

Data was collected following best practice standards in soil measurement. This was done for the profile down to 30 cm of depth and 1 meter of depth. Once collected the samples, apparent density and carbon content are estimated.

The most commonly used method for calculating soil organic carbon stocks at equivalent volume is to measure C stocks for each layer and taking into account apparent density and coarse content (EG: stoniness) of the soil. . The calculation of carbon stock in mega grams

	of C per hectare (Mg C / ha, or tonne of C per hectare t C / ha) is done using the equation presented below: SOC_i= DA x 0,1 x (1 – (EG/100)) x C_{org} x e Where: SOCi : Carbon stocks in depth i (i = 0-10 cm, 10-20 cm, 20-30 cm), en tC/ha; DA : Aparent density, en g/cm3 ; EG : Percentage of gross elements > 2 mm, in %; Corg : Organic carbon content, en g C/kg ; e : Depth of the horizon, in cm (ici e = 10 cm). The SCO for depths of 0 to 30 cm (SCO_30) were obtained by summing the stocks calculated for each thickness (0-10cm, 10-20cm, 20-30cm) (PERR-FH. 2015). The corrections necessary to take into account the presence of coarse elements have been applied; thus, the mineral fraction greater than 2 mm (EG), being supposed to be devoid of C was thus removed from the stock. In this sense, for the first 30 cm of soil, the volume equivalent stock is calculated with the following equation: SCO_30 = SCO_{0-10} + SCO_{10-20} + SCO_{20-30} The link to the document showing this equation is : https://drive.google.com/file/d/1r5a7zylbp0XJala0dY4MJT0Lhxv0URT_ Les stocks de C à volume équivalent ont été principalement utilisés pour la cartographie et la modélisation du carbone du sol. ***C/ Inference*** The soil organic carbon stocks are estimated and provided in the following table *Estimates of SOC for forest and non-forest according to PERR-FH* **Class** / **SOC (tdm/ha)** / **N** / **Standard deviation** *Forest* / 110.97 / 125 / 39.17 *Non-Forest* / 104.65 / 75 / 37.53 These estimates were then assigned to all classes including primary forest and modified natural forest.
Value applied:	**Class** / **Value** Primary Forest (PF) / 110.97 Modified Natural Forest – Disturbed Forest (DF) / 110.97 Modified Natural Forest – Secondary forest (SF) / 110.97 Modified Natural Forest – Agroforestry (DF) / 110.97 Plantations – plantations for wood / 0 Non-Forest / 104.65

QA/QC procedures applied:	
Uncertainty associated with this parameter:	The sampling error is provided below. **Estimates of SOC for forest and non-forest according to PERR-FH** <table><tr><th>*Class*</th><th>90% level – confidence interval</th></tr><tr><td>*Forest*</td><td>5%</td></tr><tr><td>*Non-Forest*</td><td>7%</td></tr></table>
Any comment:	

8.4 Estimated reference level

ER Program reference level

Table 22: ER program reference level

Crediting Period year *t*	Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical removals by sinks over the Reference Period (tCO_{2-e}/yr)	Adjustment, if applicable (tCO_{2-e}/yr)	Reference level (tCO_{2-e}/yr)
2020	11,442,849	420,060	-13,254		11 849 654
2021	11,442,849	420,060	-26,508		11 836 401
2022	11,442,849	420,060	-39,762		11 823 147
2023	11,442,849	420,060	-53,016		11 809 893
2024	11,442,849	420,060	-66,270		11 796 639

Calculation of the average annual historical emissions over the Reference period

Average annual historical emissions over the Reference period have been estimated using all equations described in Chapter 8.3. Activity data are multiplied by Emission Factors and Removal Factors in order to estimate emissions from deforestation and degradation, and removals from carbon stock enhancement in new forests. Please note that the underlying activity data has been determined on the basis of the so-called “adjusted” areas, defined during the assessment of the accuracy of change detection which is considered good practice.

A summary of annual historical emissions is presented below.

- Emissions from deforestation amount to **11,442,849 TCO2e/an**.
- Emissions from degradation amount to **420,060 TCO2e/an**.
- Carbon stock enhancement of amounts to **13,254 TCO2e/an**.

8.5 Upward or downward adjustments to the average annual historical emissions over the Reference period (if applicable)

Not applicable.

8.6 Relation between the Reference Level, the development of a FREL/FRL for the UNFCCC and the country's existing and emerging greenhouse gas inventory

a. ***Consistency with the national GHG inventory***

Madagascar submitted its initial communication in 2004, its second communication in 2010 and its third communication in 2017, but has so far not submitted a biennial Update report. The 2017 national communication covers the year 2010. The approach used in the 2010 Inventory to estimate emissions and sinks in the forestry sector is similar to the one used in 2017 to estimate emissions from the ER-P area and emissions at the national scale, however some differences are noted with respect to the following parameters:

- The national inventory takes 2010 as a reference year whereas the REL of the ER-P uses a reference period from 2006 to 2015. It is clear that a year (2010) is a too short period to be used as a reference period and that the year chosen is too early and therefore cannot be considered for the purpose of the development the REL.
- The national inventory of GHG takes into account changes in land cover according to the IPCC good practice 2000 and 2003, but does not take into account more detailed classifications such as dense rainforests or degraded rainforests and related land cover changes. Instead, in the context of the ER-P, it was decided to take these classes into account in order to allow more specific emission factors to be applied and thus increase the overall accuracy.
- The GHG inventory includes: CO_2 CH_4 and N_2O, while the REL-ER only concerns the CO_2. This is due to the fact that the OSCOSF inventory was based on a dataset dealing with biomass burning, which explains why data availability was limited to the year 2010. However, for the reference period, we did not apply the analysis used to estimate the activity data, which did not generate clear indications of burnt areas and thus the IPCC forest fire modules, which could have been used to estimate emissions of CH_4 and N_2O.

Madagascar is in the process of implementing a national forest monitoring system, which is currently led by the Forest Observation Laboratory of Madagascar (LOFM) implemented within the framework of BNCC REDD+. The LOFM develops activity data, while the methodological division generates emission factors, once the new underlying data is available, that is to say new additional volume data, the determination of additional tree species names (which is currently perceived as the weakness of the national forest inventory) and/or determination of density factors specific to additional tree species.
The GHG inventory and national communications are prepared by the BNCC REDD+ Climate Change Service. Bearing in mind that the national forest monitoring system led by the LOFM generates data activities, as well as new emission factor through the Methodological Division, the laboratory provides these data to the Climate Change Service, which will ensure consistency of the data used for the GHG inventory.

b. ***Consistency with the national REL***

Acting on behalf of Madagascar, the BNCC REDD+ developed the country's Forest reference emission level / Forest reference level (FREL/FRL) and submitted it to the UNFCCC in 2017 and updated it in 2018. Submission is mainly based on existing data, not generated as part of the REDD readiness process and the main objective of the exercise was to learn from the process and to draw lessons that could inform the design of emerging NFMSs. The national FREL/FRL currently needs to be updated in relation to the changes in methodology and availability of current data. The FREL of ERPAA is currently bieng updated and the carbon performance monitoring is ongoing.

However, some differences and similarities in technical design features are noted between the national FREL and the ER-P REL and can be summarized as follows:

- The reference period of the national FREL/FRL and that of the ERPAA runs from 2006 to 2015, as required by Criterion 11 of the Methodological Framework.
- The national FREL covers four ecosystems, including that of rainforests, as covered by the ER Program area. The estimate of total emissions from the forestry sector for the national REL is based on ecosystem-specific inventory data. The ER Program, instead, only covers the total rainforest ecosystem. As a result, for determine of emission factors, we only used data from plots located within the boundaries of the ER Program area. In addition, the ER Programm uses a different stratification (including dense rainforests, degraded rainforests and secondary forests) and includes new inventory data from plots located within the ER Program area in order to measure the biomass stock of these strata.

In more general terms, as stated in the National Forest Reference Emission Level, it is envisaged to use the REL of the ER Program to inform the national REL because of its greater specificity and accuracy.

The processes of developing the initial FREL, its validation, as well as the development of the REL ER-P are based on learning processes. Madagascar should develop a revised national FREL (including the ER Program area) which would be based on previous learning processes and whose reference period would be consistent with the reference period of the REL of the ER-P.

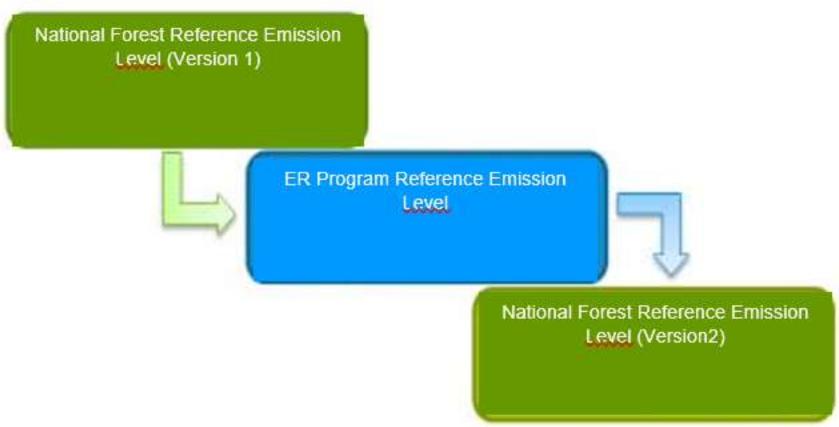


Figure 5 : FREL development process

9 **Approach for measurement, monitoring and reporting**

9.1 Measurement, Monitoring and Reporting Approach for estimating emissions occurring under the ER Program within the accounting area

a- Forest Monitoring System overall structure (FMS)

The ER Program's Forest Monitoring System (FMS) is incorporated into the National Forest Monitoring System (NFMS) currently under development. This NFMS was established in accordance with Copenhagen Decision 4/C.15 and has two main functions: a monitoring function and a Measurement, Reporting and Verification (MRV) function. The **monitoring function** consists of monitoring legal compliance, safeguards, and other aspects of the ER program. The **MRV function** of the NFMS is strictly related to estimating, reporting and verifying GHG emissions and removals.

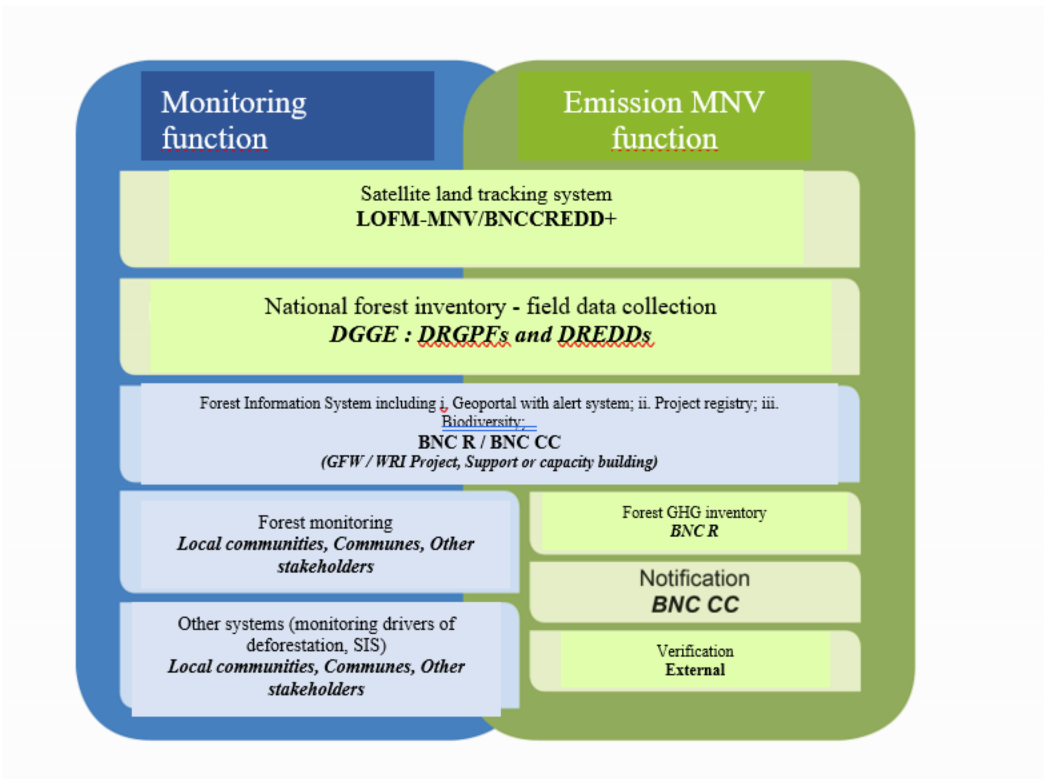


Figure 6 : NFMS structure

b- FMS Design Principles

Emissions by sources and removals by sinks measured, monitored and reported by the FMS are consistent with those reported by the RL, as required by Criterion 14 of the Methodological Framework. This is achieved through four key principles:

- **Consistent field of application**: the same scope in terms of geographic area, REDD+ activities, carbon pools and GHGs are maintained with respect to the RL (Indicator 14.1 of the FC MF);
- **Activity Data (AD)** : Data on the extent of human activity resulting in emissions or removals that occur during a given time period are measured and monitored using the same methods used for its definition under the RL (Indicator 14.2 of the FC MF);
- **Emission factors (EF) and default values:** the same EFs and default values used for RL are used in the estimation of GHG emissions by sources and removals by sinks (Indicator 14.3 of the FCM);

- **GHG Accounting:** the same equations, calculation procedures and QA/QC used for the RL are used (Indicator 14.1 of the FC MF).

This means that the ADs are the only parameters changed from the RL. Considering the methods described in Chapter 8, this means that only one parameter will be measured:

Table 2 : Activity data

	Activity data	Source
$A(j,i)$	Annual conversion from forest type (dense humid forest, degraded humid forest) to non-forest land uses i (non-forest)	Deforestation
$A(i,j)$	Annual conversion of non-forest land use i to forest type j (planted or secondary forest)	Carbon stocks improvement (afforestation / reforestation)

c- Measurement, monitoring and reporting process.

The overall measurement, monitoring, and reporting process consists of all EO data collection operations, QA operations, and final reporting. A general overview of the FMS process is provided in the following simplified process diagram. Each of the operations is described in the following sections.

DATA COLLECTION AND PROCESSING

Data collection and processing is carried out to produce Activity Data in the form of: land use subcategory/strata conversion area (A (j,i), A(i,j)). The main specifications for data collection and processing are given in the following table.

Table 23: Parameters to be monitored

Parameter:	$A(j,i)$ $A(i,j)$		
Description :	• Annual conversion from forest type j (primary forest, modified natural forest), to non-Forest Land uses i (Non-Forest) in the monitoring period • Annual conversion from forest type j (primary forest), to forest type i (modified natural forest and plantations) in the monitoring period • Annual conversion from non-Forest Land use i to forest type j (planted forest or modified natural forest) in the monitoring period		
Data unit:	ha/year		
Value monitored during this Monitoring / Reporting Period:	**Activity**	**Type**	**Area (ha/year)**
	Deforestation	Dense humid forest	678
		Degraded humid forest	16,553.71
		Secondary forest	0
		Agroforestry	0
		Plantations	0
	Degradation	PF to Disturbed forest	19,888.22
		PF to Agroforestry	0
		PF to Plantations	0

		DF to Agroforestry	0
		DF to Plantations	0
	Enhancement	Secondary forest	0
		Agroforestry	0
		Plantations	0

Source of data and description of measurement/calculation methods and procedures applied:

Sampling design:

Estimator:

Stratified random estimator of a proportion

Stratification:

A forest cover change map was created as stratification criteria. More information on the methods for production of the maps is provided in SOP0 ().

Stratification used for the activity data estimation

Strata
11-Forest
12-Deforestation
22-Non-forest
55- Buffer Forest 50 m-100 m
56- Buffer Forest 0-50 m

Precision and confidence level:

Relative margin of error of 20% at 90% of confidence level as requested

Calculation of the sample size:

For the calculation of the sample size, the equation from Cochran (1977, Eq. (5.25)) was used assuming that the cost of sampling each stratum is the same:

$$n = \frac{(\sum W_h S_h)^2}{[S(\hat{O})]^2 + (1/N)\sum W_h S_h^2} \approx \left(\frac{\sum W_h S_h}{S(\hat{O})}\right)^2$$

Where:

W_h Weight of stratum *i*;

S_h Standard deviation of variable of interest in stratum i;

$S(\hat{O})$ Standard error of the variable of interest;

N Number of sampling units in the region of interest (i.e., population size);

The sample size was estimated through an iterative approach and using proportion of total deforestation as the variable of interest:

- First of all, 100 sampling units were collected per stratum.
- A calculation of the sample size was done, and as a result 300 additional samples were added in all strata.
- A new calculation of the sample size was done and resulted in 250 additional samples added to each stratum.

Sample allocation was based on a proportional approach as shown in the below table.

Calculation of number of samples per stratum

Code	**Class**	Stratum weight	Number of sample

11	Stable Forest	0.1771	300
12	Deforestation	0.0036	150
22	NF Stable	0.6886	150
55	Buffer Forest 50-100	0.0637	272
56	Buffer Forest 0-50	0.0669	1,074

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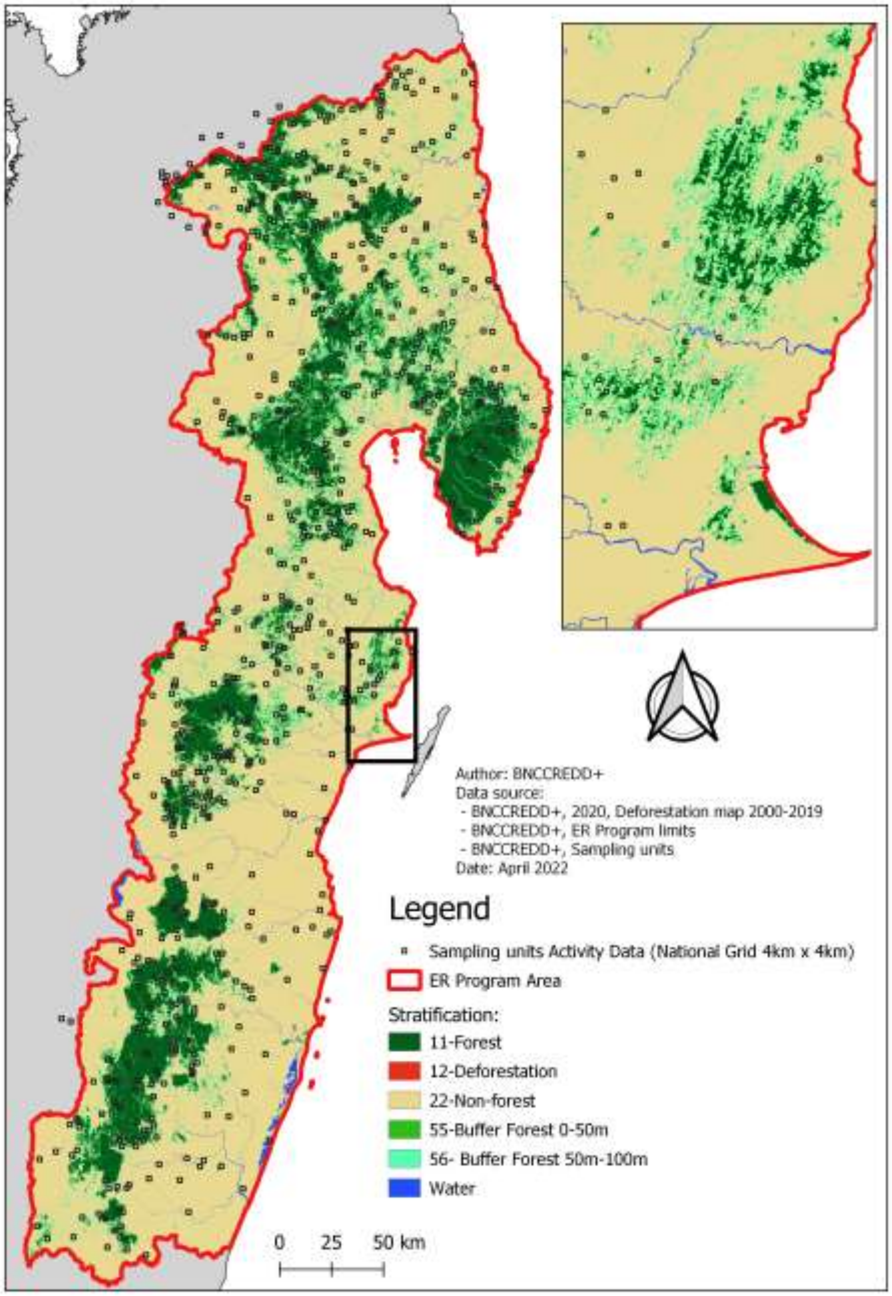


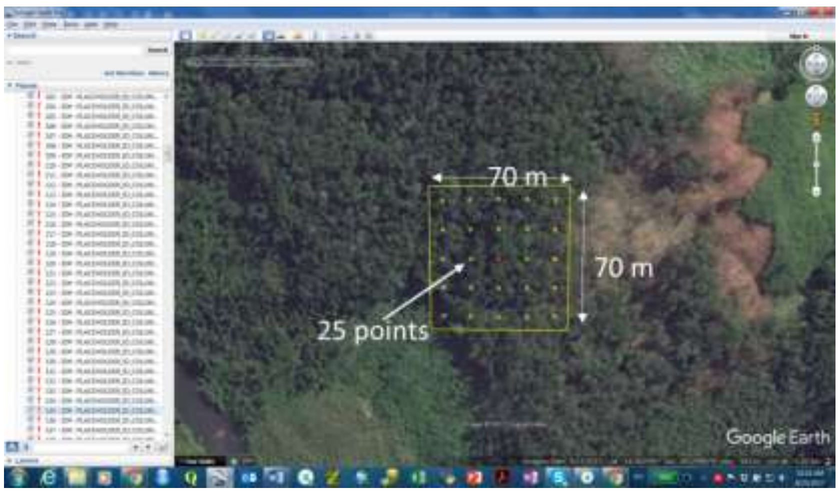
Location of sampling units and stratification

Response design

Spatial assessment unit:

The spatial assessment unit is a squared area of 70 meter of side which contains 25 points inside and which is centered on the random point selected from the sampling frame. Considering the acceptable geolocation error of Landsat imagery is 30 meters, this spatial assessment unit would be justified.

However, in terms of spatial support the information beyond the limits of the plot were used to assess whether one object within the assessment unit would comply with the minimum mapping unit.



Assessment or sampling unit

The same sampling unit (square of 70 m x 70 m) was used for the data collection.

Data collection by interpreters :

:

Interpreters assess sample units, using the interpretation key as a guide to assess different land use classes and transitions. The interpreters consult each other and the Laboratory Manager if they have any doubts about the interpretation of the image.

The Laboratory Manager organizes a validation based on a set of samples evaluated by two or more interpreters.

During data collection, the Laboratory Manager encourages discussions and a group evaluation of the samples with all the interpreters for mutual validation and good calibration with a common understanding of the techniques by the group.

The Laboratory Manager notes challenges and limitations during data collection as well as potential sources of bias during data collection.

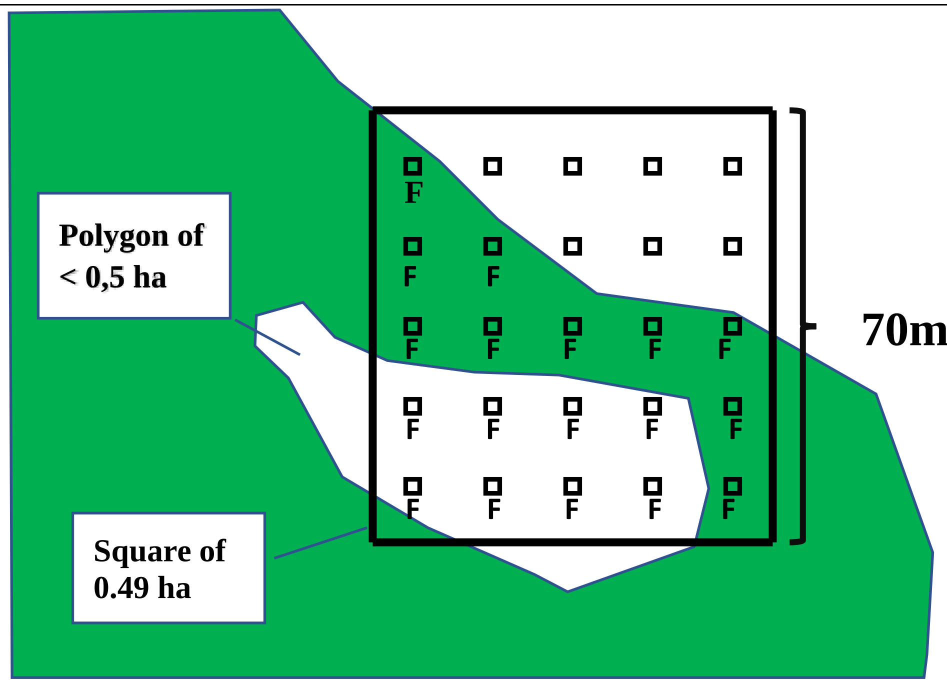
Data assembly :

Once data collection is complete, the Laboratory Manager compiles a data set which should include the following information:

• A database of sample data collected by interpreters including:

o Geographic coordinates defined in the coordinate or projection system

	o The unique identification code for each sample unit o The interpretation of all sample units, including the previous interpretation(s) of the sample unit in case this has been revised or corrected. ▪ QA/QC : A number of QA/QC procedures have been applied: Quality Assurance/Quality Control (QA/QC) : The interpreters reanalyze the individually collected data (taking a random percentage of samples (in our case, 20%)) by inverting the collection results. The results are then, if necessary, reanalyzed as a group during a series of sessions during which all samples with changes are reanalyzed. Samples with doubt are also closely reviewed. The total of these samples must constitute 5 percent of the number of sampling units. *Source of data:* The data in this case was collected through visual interpretation of all satellite imagery available to the country. This includes : ▪ Planet basemap: from 2016 to 2021, with 3m high resolution imagery available through the NICFI grants to tropical countries. Planet data has more recent imagery compared to other high resolution satellite images. ▪ Google Earth and Bing: All high and very high-resolution imagery accessible through Google Earth and Bing. The spatial coverage of very high-resolution imagery in the ER program area is relatively high, with many areas with coverage from 2005 to 2015. ▪ Aster: Resolution of 15 meters from 2000 to 2009 ▪ Landsat 5 TM and 7 ETM+: Available through google earth engine. ▪ Landsat 8 OLI: Available through google earth engine for 2013-2017. ▪ Sentinel 2A MSI: Available through google earth engine for 2015-2017. It is considered that these are reference data as most of the interpretations will be based on direct interpretation of higher resolution imagery for different periods which provides the necessary temporal contextual information. *Reference labelling protocol* ▪ Forest/Non-Forest classification: In order to attribute the condition of forest to the sample, the interpreter evaluated how many points of the grid would fall over forest (a differentiated object that has at least one ha in area and has 30% of tree canopy cover). If at least 13 points (>50% of points) fall in forest, the point would be classified as forest, otherwise as non-forest. This method ensures that there is not a overrepresentation of forest, which happens with hierarchical classification systems. In the example below, although only 10 points fall over canopy, 18 points fall in forest area, so the sampling unit is classified as forest.



Example of interpretation of sampling unit

- Forest types: If the sample is classified as forest, the sample would then by attributed to one of the 5 forest types based on the majority class present:
  - Primary forest
  - Modified Natural forest – Disturbed forest
  - Modified Natural forest – Agroforestry
  - Modified Natural forest – Secondary forest
  - Plantation – Plantation for wood
- Interpretation has been based on a protocol found in this link (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-linterpretation-des-donnees#)

The results of the interpretation are the following:
Sampling units per strata

		Strata			
Activity	**Type**	**1**	**5**	**10**	**9**
Deforestation	Primary forest	1	14	0	0
	Disturbed forest	5	42	0	1
	Secondary forest	0	0	0	0
	Agroforestry	0	0	0	0
	Plantations	0	0	0	0
Enhancement	Secondary forest	2	2	0	0
	Agroforestry	0	0	0	0
	Plantations	0	0	0	0

Degradation	PF to Disturbed forest	54	29	3	0
	PF to Agroforestry	0	0	0	0
	PF to Plantations	0	0	0	0
	DF to Agroforestry	0	0	0	0
	DF to Plantations	0	0	0	0
Total number of samping units		677	677	699	422

Verifications with ancillary data :
:
If external data exists, the Laboratory manager uses these external data sources (eg maps, etc.) to make a comparison with the classification of the sampling unit. Discrepancies between the two sets of data can be reported by the head of the Laboratory. Confirmed differences between the two datasets can be documented to show why sample-based area estimation may yield different results compared to other data sources.

Performance evaluation
By having the .csv data of the activity data and the stratification map in raster version, or the .csv table of the proportion of each stratum with the surfaces in number of pixels and in hectares, as well as the number of samples per stratum, a matrix of proportions is established. Analysts build a matrix that shows strata (map classes) and reference classes. The matrix lists the numbers of sampling units and areas of the stratification map.

An error matrix is obtained which is recorded. Analysts then calculate stratum weights by dividing the area of each class or stratum by the total reporting area. We obtain a table on the area and the weight of the strata using an R script and we must retrieve the file area_stratum.csv, and calculate the weight of the stratum.

Analysis design
The average proportion of the variable of interest in the reference period will be estimated through the stratified random estimator of the mean ($\hat{\mu}_{STR}$)

$$\hat{\mu}_{STR} = \sum_{h}^{H} W_h \hat{\mu}_h$$

Where:
W_h Weight of stratum *h*;
$\hat{\mu}_h$ Sample estimates within stratum *h* which is equal to $\hat{\mu}_h = \frac{1}{n_h}\sum_{k=1}^{n_h} y_{hk}$ where y_{hk} is the i^{th} sample observation in the h^{th} stratum
In order to convert the proportions to areas, the average proportion is multiplied by the total area of the region of interest of 6,914,785 ha.

Estimate of proportions per class

Activity	**Type**	**Stratified estimate (proportion)**	**Area estimate (ha)**
Deforestation	Dense humid forest	0.00009	678
	Degraded humid forest	0.0023	16,554

Official Use

		Secondary forest	0.0000	0
		Agroforestry	0.0000	0
		Plantations	0.0000	0
	Enhancement	Secondary forest	0.0000	0
		Agroforestry	0.0000	0
		Plantations	0.0000	0
	Degradation	PF to Disturbed forest	0.003	19,888
		PF to Agroforestry	0.0000	0
		PF to Plantations	0.0000	0
		DF to Agroforestry	0.0000	0
		DF to Plantations	0.0000	0

The proportion of deforestation or afforestation/reforestation is expressed in an annual basis.

Estimate of activity data per class

Activity	**Type**	**Area (ha/year)**
Deforestation	Dense humid forest	678
	Degraded humid forest	16,553.71
	Secondary forest	0
	Agroforestry	0
	Plantations	0
Degradation	PF to Disturbed forest	19,888.22
	PF to Agroforestry	0
	PF to Plantations	0
	DF to Agroforestry	0
	DF to Plantations	0
Enhancement	Secondary forest	0
	Agroforestry	0
	Plantations	0

More information is provided in the spreadsheet "MADA_CalculRE_v00_20211109_update_for_ER_Report_version_6" and https://drive.google.com/file/d/1QQtpS_4RpcF9rKIARd-eBE0YMeRa5H4C

QA/QC procedures applied::

- QC procedures in this case consist in the establishment of a Standard Operating Procedure (SOP) for the interpretation of the samples and the application of training procedures in order to ensure the correct implementation of SOPs (https://www.environnement.mg/?wpdmpro=standard-doperation-pour-linterpretation-des-donnees#)

The labeling or assignment of a class to a sample is triple checked:

<table>
<tr><td></td><td>- A first time, by the analyst or interpreter who interprets the satellite images for the year or study period and on the basis of different sources (Landsat, Sentinel, Google Earth, etc.);
- During QA/QC: for quality assurance, a random 20 percent of the samples is checked by another analyst (exchanges of results files) who is taken at random according to the organization set by the Laboratory Manager; rectification is made in the event of an error of interpretation;
- During QA/QC: for quality control, samples with low confidence, samples with changes (deforestation, degradation and forest gain) are re-analyzed by the team concerned who form a discussion and validation committee for the output of the final result. The overall total retested should be at least 5 percent of the total number of samples. Rectification is made in the event of an error of interpretation. It is also important to pay attention to the following point during the interpretation: The distinction between deforestation and forest remaining burnt forest must imperatively be made by exploiting all the sources of information available from the archives of satellite images because it is proved that a forest remaining forest that is burned, is not necessarily a land use conversion.</td></tr>
<tr><td>Uncertainty for this parameter:</td><td>
<table>
<tr><th>Activity</th><th>Type</th><th>Standard error (proportion)</th><th>90% confidence – Relative margin of error</th></tr>
<tr><td rowspan="5">Deforestation</td><td>Dense humid forest</td><td>0.00004</td><td>81%</td></tr>
<tr><td>Degraded humid forest</td><td>0.0002</td><td>17%</td></tr>
<tr><td>Secondary forest</td><td>-</td><td></td></tr>
<tr><td>Agroforestry</td><td>-</td><td></td></tr>
<tr><td>Plantations</td><td>-</td><td></td></tr>
<tr><td rowspan="3">Enhancement</td><td>Secondary forest</td><td>-</td><td></td></tr>
<tr><td>Agroforestry</td><td>-</td><td></td></tr>
<tr><td>Plantations</td><td>-</td><td></td></tr>
<tr><td rowspan="5">Degradation</td><td>PF to Disturbed forest</td><td>0.001</td><td>51%</td></tr>
<tr><td>PF to Agroforestry</td><td></td><td></td></tr>
<tr><td>PF to Plantations</td><td>-</td><td></td></tr>
<tr><td>DF to Agroforestry</td><td>-</td><td></td></tr>
<tr><td>DF to Plantations</td><td>-</td><td></td></tr>
</table>
</td></tr>
<tr><td>Any comment :</td><td>-</td></tr>
</table>

CALCULATION

To implement the process, the same IPCC methods and equations described in Chapter 8 are used to estimate GHG emissions over the follow-up period.

Once the identified changes in carbon stocks during the ER program are estimated for each activity i (the GHG emission reductions that are generated by the program should be determined. The following equations are applied:

$$ER_{LU} = \sum_{i} \sum_{t}^{T} (RL_{i,t} - \Delta C_{LU,i} \times T)$$ Equation 19

Where:

ER_{LU} = GHG emissions reduction; tCO2e year r^{-1}

$RL_{i,t}$ = GHG emissions from the RL in the REDD+i activity in year t; tCO2e year^{-1}.

T = Years in follow-up period, year

The uncertainty of GHG emission reductions should be estimated through Montecarlo methods, as described in the IPCC GL of 2006- Volume 1 - Chapter 3.
The final uncertainty reported in the FCPF CF MF for deforestation and degradation will be used to define the conservativeness factor to be applied to determine the amount set aside in the buffer reserve.

<u>Table 3</u> : Conservativeness factors to be applied to emission reductions as defined by the FCPF CF

Overall uncertainty of emission reductions	**Conservativeness factor**
= 15%	0%
> 15% et = 30%	4%
> 30 et = 60%	8%
> 60 et =100%	12%
> 100%	15%

$$ER_{LU} = \sum_{i}\sum_{t}^{T}(RL_{i,t} - \Delta C_{LU,i} \times T) \times (100 - CF_i)/100 \qquad \text{Equation 20}$$

Where:

CF_i = Conservativeness factor for REDD activity + i; percentage

REPORT

Once emission reductions have been calculated, they will provide all information in a transparent way, demonstrating that the principles outlined in Chapter 9.1 have been followed. The following information is reported:

- Record of measured and monitored parameters;
- Reduction of total emission;
- Reduction of disaggregated emissions:
  - REDD+ activity and sub-activity
  - By participant in the benefit-sharing mechanism.
- Existence of reversals

9.2 Organizational structure for measurement, monitoring and reporting

a. ***Organizational structure, responsibilities and competences***

The government of Madagascar is establishing a National Forest Monitoring System (NFMS) that also fulfils the monitoring and reporting functions of emissions and potential emissions reductions of the ER program in the country. The monitoring system is based on the following key elements:

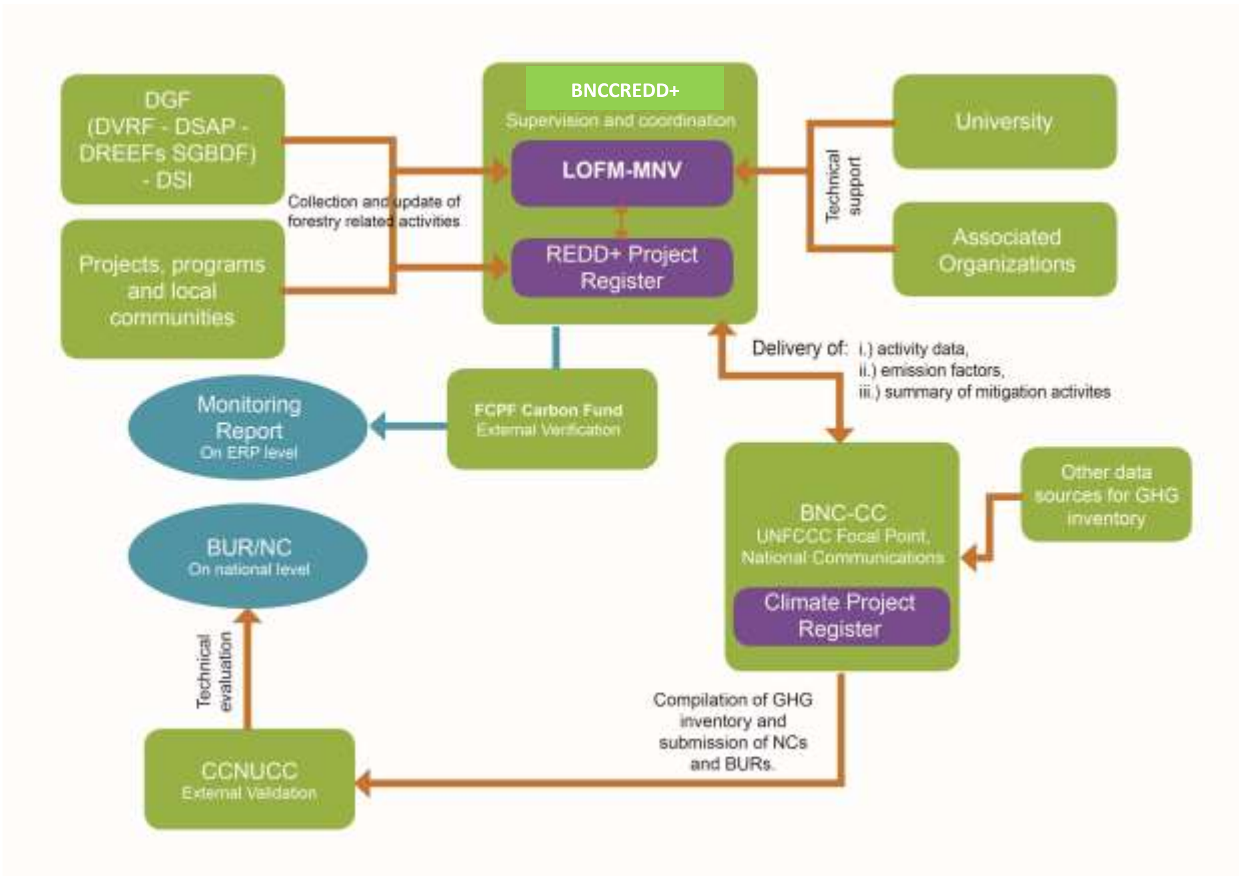
- The BNCCREDD+ has overall responsibility for the assessment of land use change and the development of the ERP monitoring report. This applies not only to FCPF-related reporting, but also to the national reporting of net GHG emissions from the forest sector.

The underlying remote sensing analyses were performed by LOFM. LOFM produces the activity data for the ER program (following the procedures specified in Chapter 9.1) and also determines the activity data for national-scale monitoring of emissions and removals.

The BNCCREDD+ also maintains a REDD+ project registry that ensures a standardized data flow from REDD+ projects in the ER program area (VCS CAZ and Makira projects) and nationally to the BNCCREDD+. Data includes tracking of results, loss events, and carbon sales to ensure prevention of double counting.

- National data (activity data, emission factors and information on mitigation measures in the forestry sector) will be submitted to the Climate Change Unit of the BNCCREDD+ for use in the national GHG inventory and at the time of the submission of National Communications and Biennial Update Reports to the UNFCCC.
- The Department in charge of forests (including the DRLFM responsible for implementing the national forest inventory) will provide new inventory data to the BNCCREDD+ once it is available. One of the current difficulties is that inventories in Madagascar include a considerable number of species that are either unknown or identified only by their common names. However, if the scientific names are unknown, this prevents the identification of species-specific density parameters for calculating carbon stocks. The results from various inventories carried out in Madagascar have made it possible to enrich these scientific names. The same applies to the collection of herbariums and the results from the Tsimbazaza zoological park.
  Additional information on tree species, as well as new inventory data, may lead to more accurate carbon stock estimates and possibly updated emission factors.
- Local communities and REDD+ projects can provide information on yield, illegal logging activities, loss events, poaching, and irregularities in the REDD benefit-sharing process. Community-based monitoring activities are particularly anticipated in those areas where government presence is weak.
  Community monitoring will be based on smartphones that are linked to a national NFMS geoportal. Initial field tests of community monitoring have been conducted and the geoportal will be in cooperation with Global Forest Watch.
- The BNCCREDD+ compiles the results of Measurement, Monitoring and Reporting activities into a monitoring report that will be submitted to the FCPF Carbon Fund for external verification.

The organizational structure of the Monitoring, Reporting and Verification system (i.e., the functions of the NFMS that are limited to accounting for emissions/removals) is shown in the figure below.



<u>Figure 7</u> : Organizational Structure for Reporting Emissions

a. ***Methods and standards for generating, storing, combining and reporting data***

Monitoring data will be generated according to the procedures specified in Section 9.1 and will be consistent with the ER program's approaches to forest definition, forest type definition, activity selection, pre-treatment and treatment methods, emission factors, change category uncertainties, and overall uncertainties, etc.

The data will be stored and published in a geoportal that is an inherent part of the NFMS system. The inventory portal will be developed by the World Resource Institute in cooperation with MESD and managed by LOFM.

This approach will ensure that the data is properly stored when it is publicly available.

b. ***Integration of the MMR system into existing systems***

It is important to note that to date, Madagascar does not yet have a fully operational forest monitoring system into which the measurement, monitoring and reporting efforts of the ER program could be integrated. However, there are the following osculation points:

- For data related to emission factors, the monitoring system of the ER program is based on the existing forest inventory system constituted by the national forest inventory, PERR-FH data as well as new inventory data generated in 2020 aimed at better understanding degradation and non-forest biomass.
- In addition, MMR will feed the web-based geoportal, which will also include data from Global Forest Watch (GFW). However, it is important to note that GFW data will not be used for emissions monitoring, but simply to provide near real-time information.

  This will allow the performance of REDD+ activities to be assessed between monitoring events and, equally important, will provide early information on potential major loss events that will then be validated by the ER on site program.

The measurement, monitoring and reporting system of the ER program will be integrated into the national reporting system to the UNFCCC. The climate change service acts as the national focal point for the UNFCCC and prepares the National Communications, Biennial Update Reports and the underlying GHG inventories. To this end, the REDD+ department will inform the climate change department on the following issues:

- Provision of new updated activity data;
- Information on change in emission factors / new underlying data;
- Summary of REDD+ measures and related forest policies, underlying efforts, outcomes, and barriers

This information will allow the BNCCREDD+ to integrate forestry sub-sector data into the LLULUCF sector ensuring high quality data to inform the UNFCCC.

9.3 Relation and consistency with the National Forest Monitoring System

The National Forest Monitoring System is being developed by key government agencies in Madagascar under the leadership of MESD. This has led to the design of the ER program's MMR as an inherent part of the National Forest Monitoring System described above. Please refer to Section 9. 2.

12 Uncertainties of the calculation of emission reductions

12.1 Identification and assessment of sources of uncertainty

Table 24: Sources of uncertainty

Sources of uncertainty	**Analysis of contribution to overall uncertainty**
Activity Data	
Measurement	This source of uncertainty applies to cases where activity data are based on sampling. This source is related to the visual interpretation of operators and/or field positioning and can be the source of both systematic and random error. This source of Error is generally high, as evidenced by recent studies. Methods for quantifying this source of Error are under research and have not been applied in operational contexts. Therefore, countries will address it through solid quality control procedures that deal with both systematic and random errors. Solid quality control procedures include: • Written standard operating procedures including detailed labeling protocols; • Use of an adequate imaging source and multiple imaging sources for labeling; • Procedures for training interpreters to ensure proper implementation of SOPs; • Reinterpretation of a number of sample units to ensure that SOPs are properly implemented and to identify areas for improvement.
Representativeness	The sampling is spatially balanced (stratification) and random so the sample is representative of the whole population. Hence, it is considered that this source is negligible.
Sampling	Sampling Uncertainty is the statistical variation in the area estimate for forest transitions that are reported by the ER Program. This source of Error is random, but the selection of the estimator can be a source of Error. ER programs should use reference data and unbiased estimators to estimate activity data and uncertainty, as recommended by the GFOI MGDSee FAQ Area Estimation and MGD Section 5.1.5 of MGD (GFOI 2016), Good Practices for Estimating Areas and *Evaluating olofsson et coll. Section 5.1.5 (2014),* for more information on how estimates can be produced using unbiased estimates of activity data. The choice of an appropriate estimator would also be a source of uncertainty that must be addressed through quality control procedures.
Extrapolation	Not applicable since no extrapolation was done, i.e. activity data was estimated directly through the sampling approach without using auxiliary data.
Approach 3	This source of uncertainty exists when there is no tracking of lands or IPCC Approach 3. This occurs in cases when, for instance, an ER Program conducts two independent surveys to estimate activity data in period 1 and period 2 (e.g. dividing the reference period in two subperiods) without conducting tracking of lands. In this example, there is a risk that transitions

Sources of uncertainty	Analysis of contribution to overall uncertainty
	are counted twice. For instance, if a unit of land transits from forest to non-forest, and then back to forest and then non-forest, there is a risk that deforestation is "double counted" if there is not a system to ensure tracking of lands. Solutions in this case are to avoid independent surveys (through permanent sample units) or to define transition rules and ensure that interpreters look at the past history of the sample unit to ensure that the transitions rules are respected. This is mitigated through the introduction of strong QA/QC measures. This source of error is not applicable because becoming a forest counts several years. In addition, the activity data is counted by type of change.
Emission factor	
DBH measurement *H measurement* *Plot delineation*	Measurement of DBH, height, and plot delineation are subject to errors. Errors may be caused by multiple factors such as poor training, poor measurement protocols, etc. While measurement errors are significant at the tree level, they usually average out at plot level and inventory level (Chave et al. 2004). Picard et al. (2015) also found the measurement error to be small when compared to the other errors. The FMT conducted an assessment of the contribution of this source of error (c.f. Annex) and found that this source of error should be negligible for Emission Reduction estimation, provided minimal QA/QC procedures are in place. The contribution of this source of error to random error is low, yet QA/QC procedures should be in place to avoid systematic errors. The error during the inventory is DBminimal because on the one hand the training of the team was well organized and on the other hand most of the team already have experience in inventory
Wood density estimation	The basic wood density or Wood Specific Gravity (WGS) cannot be easily measured during forest inventories, and it is usually sourced from peer-reviewed publications and global databases. Chave et al. (2004) assumed that the error of this predictor was +/- 10% of the actual values. WSG values used L have been sourced from different publications using a decision tree and strong QA/QC procedures to ensure the most accurate or conservative value. Research in Madagascar by Ramananantoandro et al. (2015) has shown that WSG values from literature overestimate measured WSG by 16% on average. However, effects on biomass estimates were found to be not significant at the 95% confidence level (c.f. section 12 of ERPD) so this has been neglected.
Biomass allometric model	The allometric model error can be divided in the following sources. a. the error due to the uncertainty of the model's coefficients;

Sources of uncertainty	Analysis of contribution to overall uncertainty
	b. the error linked to the residual model error; c. the selection of the allometric model. According to Picard et al. (2015) [§§] the largest uncertainty is due to the selection of the allometric model which may be 77% of the mean biomass estimate. Van Breugel et al. (2011) [***] estimated that the errors linked to the allometric equation could vary from 5 and 35% depending on the model selected. The third error is assumed to be negligible for the woody biomass species as these equations are calibrated with trees measured within the same ecoregion or even the ER program area. The other two errors were found to be not significant at the 95% confidence level (c.f. section 12 of ERPD) so this has been neglected.
Sampling	This error is one of the main sources of errors. This will be considered in the quantification of uncertainty.
Other parameters (e.g. Carbon Fraction, root-to-shoot ratios)	Uncertainty from other parameters, such as root-to-shoot ratios and CF will be propagated. Selection of parameters was done in accordance with the IPCC Guidelines and guidance ensuring the most accurate or conservative estimate.
Representativeness	The lack of representativeness usually causes bias, i.e. if the sample is not representative of the population. In the case of MNF this could be a source of uncertainty as the estimate is based on samples from different forest types. However, the MNF biomass stocks estimate is conservative (samples in degraded forest or single layer were not considered) in terms of reducing emissions and ERs, so it is assumed that this source of error is negligible.
Integration	
Model	Although the simple multiplication of AD and EF does not contain any error, there are some assumptions such as assuming that after deforestation there is an instantaneous transfer of AGB and BGB to the atmosphere or that the biomass in non-forest grows immediately after conversion. The former assumption is based on best practices, while the latter is conservative in terms of GHG emissions and emission reductions. Another potential source is that it is assumed that the carbon stocks of deforested forests is equal to the average of all forests, whether they are primary or not. This last assumption is partially corrected in the RL by

[§§] Picard et al. (2015) Error in the estimation of emission factors for forest degradation in central Africa. J For Res DOI 10.1007/s10310-015-0510-5
[***] Van Breugel et al. (2011) Estimating carbon stock in secondary forests: Decisions and uncertainties associated with allometric biomass models. Forest Ecology and Management 262 (2011) 1648–1657

Sources of uncertainty	Analysis of contribution to overall uncertainty
	separating the stratum of primary forest and the stratum of modified natural forest (with higher deforestation and lower biomass stocks). Another error might be the ages assumed in order to estimate the transition from non-forest to modified natural forest. This error has been taken into consideration.
Integration	This issue has been solved through the forest inventory which was based on a random sample of plots of the national grid interpreted via collect earth. This ensures the comparison of apples with apples as the emission factors are based on the forest classification observed via remote sensing, not in-situ.

12.2 Quantification of uncertainty in Reference Level Setting

Parameters and assumptions used in the Monte Carlo method

Parameter included in the model	Parameter values	Range or standard deviations		Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Source of assumptions made
		Lower	Upper			
Annual deforestation primary forest (ha/year)	2,750.24	2,087.11	3,413.37	Sampling error	Normal	Calculation of Activity data
Annual deforestation disturbed forest (ha/year)	22,518.47	20,640.77	24,396.17	Sampling error	Normal	Calculation of Activity data
Annual deforestation secondary forest (ha/year)	160.55	0	321.10	Sampling error	Normal	Calculation of Activity data
Annual deforestation agroforestry (ha/year)	160.55	0	321.10	Sampling error	Normal	Calculation of Activity data
AGB primary forest (tdm/ha)	202.63	194.63	210.63	Sampling error	Normal	Allometric equation of

						Vieilledent and al (2012)
AGB disturbed forest (tdm/ha)	186.00	173.86	198.14	Sampling error	Normal	Allometric equation of Vieilledent and al (2012)
AGB secondary forest (tdm/ha)	91.11	75.23	106.99	Sampling error	Normal	Allometric equation of Vieilledent and al (2012)
AGB Agroforestry (tdm/ha)	87.87	80.23	95.51	Sampling error	Normal	Allometric equation of Vieilledent and al (2012)
AGB plantation (tdm/ha)	29.55	23.30	35.80	Sampling error	Normal	Allometric equation of Vieilledent and al (2012)
AGB Non Forest (tdm/ha)	11.96	8.68	15.24	Sampling error	Normal	Ramananatoandro and al (2017)
Carbon fraction	0.47	0.44	0.49	Uncertainty ran ges as provided in sources	Normal	IPCC (2006). Chapter 4. Table 4.3. Normality assumption following Chabi and al. (2019)
Conversion Factor to CO2	3.67	3.67	3.67	Not applicable	Fixed	NA

Quantification of the uncertainty of the estimate of the Reference Level

Table 25: Quantification of the uncertainty of the estimate of the Reference Level

		Deforestation	Forest degradation	Enhancement of carbon stocks
A	**Median**	11,507,721	436,214	-12,447
B	**Upper bound 90% confidence interval** (percentile 0.95)	14,089,176	1,086,712	-3,366
C	**Lower bound 90% confidence interval** (0.05 percentile)	9,280,580	-161,021	-26,615
D	**90% confidence Interval at Half-Width (B - C / 2)**	2,404,298	623,866	11,625
E	**Relative margin (D / A)**	21%	143%	93%
F	**Decrease in uncertainty**			

Sensitivity analysis and identification of areas of improvement of MRV system

Referring to criterion 7 and indicators 9.2 and 9.3 of the Methodological Framework and the Guideline on the application of the Methodological Framework Number 4 On Uncertainty Analysis of Emission Reductions, a sensitivity analysis was undertaken to identify the relative contribution of each parameter to the overall uncertainty. Sensitivity analysis was undertaken by systematically disabling a parameter and noting the change in overall uncertainty of the emission reduction. This process was done by turning the parameter off (changing from include parameter = YES to include parameter = NO, noting the parameters and putting the parameter back on before moving to the next parameter, this scenario assumes the parameter is error free permitting the enhancement to the uncertainty provided by that parameter.

Table 26: Sensitivity analysis (lists only the parameters that can be controlled by the project)

Scenario	**Uncertainty 90% CI**	**Difference to ER Uncertainty 90% of all paramater**
All parameters	56	0
No reference level Deforestation	41	-15
No reference level Degradation	56	0
No reference level Enhancement	56	0
No Emission factor	52	-4
No Root to shoot ratio	56	0
No monitoring level deforestation	46	-10
No monitoring level degradation	55	-1
No monitoring level Enhancement	56	0

The difference of uncertainty compared to ER overall uncertainty are all below the threshold of 20%. However, deforestation from both reference period and monitoring period has the highest contribution to the error rate. This may be due to the fact that deforestation represent only a small fraction of the landscape and it is disproportionate to put a lot of samples in the deforestation class without the sample being too close to one another or overlapping. We will still try to monitor this parameter closely in the next monitoring period. All the other parameters have very low imprecision and the difference from including or excluding the parameter did not add more value to the uncertainty.

Table 27: Document history

Version	Date	Description
5	**February 2023**	**This is th current version, addressing the non-conformance found and recommended by the VVB**
4	september 2022	Version submitted to AENOR for the process of validation
3	August 2022	AsDocument taking in account remarks from FCPF
2	juin 2022	Enhancement of text, translated to english
1	mars 2022	The initial version , in French, sent to FCPF for comments

SEPARATE ANNEX : INFORMATION ON EMISSIONS FROM THE OUTSIDE AREA

Methodology for Tracking Leakage Outside the ERPAA Program (10 km buffer)

Leakage outside of the program area is assessed over a 10 km buffer outside of the ERPAA boundary. Annual deforestation rates from the mapping studies are compared for the entire area inside the program and the entire 10 km radius buffer around the initiative. The data used for this comparison are :

- **Historical data from the national deforestation mapping study from 2000 to 2019 (avalaible)**;

The production of this historical data had the following objectives, among others :

- o Update information on the forestry potential available at the national level ;
- o Monitoring changes from 2000-2005, 2005-2010, 2010-2015 and 2015-2019 ;
- o Support for the justification and quantification of GHG emissions from deforestation

With the following monitoring classes : Stable forest, forest loss and gain, non forest and water

- **Stratification maps of the annual monitoring periods (avalaible)** : 2020 for the monitoring period/year 2020, 2021 for the monitoring period/year 2021 nd so on until the year 2024. The area concerned are the areas of the Program and for the 10 km radius buffer zone of leakage assesment.

With the following monitoring classes : Stable forest, forest loss and gain, non forest and water

The **deforestation rates** of the entire inner Program area and the 10 km buffer zone are compared each other for the reference period (2006-2015), the year of monitoring period (2020 for the first monitoring period) and the year before the monitoring period (2019 for the first monitoring period).

The methodologies used for mapping are described in the following linked documents :

https://www.environnement.mg/?wpdmpro=rapport-final-sur-lanalyse-de-la-deforestation-nationale# (The Historical Data from the National Deforestation Mapping Study 2000-2019) which describes the methodological steps for map production in satellite land monitoring) ; https://www.environnement.mg/?wpdmpro=standard-doperation-pour-la-stratification# (Stratification maps for each monitoring periods) where are detailed the procedures for creating a map of land use and occupancy and its changes in order to prepare a stratified random probability sampling.

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