

CARBON EMISSION REDUCTION PROJECT IN THE CORRIDOR ANKENIHENY-ZAHAMENA (CAZ) PROTECTED AREA, MADAGASCAR

Project Title	Carbon Emissions Reduction Project in the Corridor Ankeniheny-Zahamena (CAZ) Protected Area, Madagascar
Version	03
Date of Issue	31 January, 2013
Prepared By	Conservation International
Contact	Léon Rajaobelina, Regional Vice President Conservation International, Madagascar Program B.P. 5178. Explorer Business Park, Batiment C2, Village des Jeux, Ankorondrano, Antananarivo 101, Madagascar Tel: +261 (0)20 22 60979

Table of Contents

1.	Project Details	3
1.1	Summary Description of the Project.....	3
1.2	Sectoral Scope and Project Type.....	5
1.3	Project Proponent.....	6
1.4	Other Entities Involved in the Project.....	6
1.5	Project Start Date	6
1.6	Project Crediting Period	9
1.7	Project Scale and Estimated GHG Emission Reductions or Removals.....	9
1.8	Description of the Project Activity.....	10
1.9	Project Location.....	23
1.10	Conditions Prior to Project Initiation	24
1.11	Compliance with Laws, Statutes and Other Regulatory Frameworks.....	25
1.12	Ownership and Other Programs	28
1.12.1	Right of Use	28
1.12.2	Emissions Trading Programs and Other Binding Limits	29
1.12.3	Participation under Other GHG Programs	30
1.12.4	Other Forms of Environmental Credit	30
1.12.5	Projects Rejected by Other GHG Programs	30
1.13	Additional Information Relevant to the Project.....	30
2	Application of Methodology	34
2.1	Title and Reference of Methodology	34
2.2	Applicability of Methodology.....	34
2.3	Project Boundary.....	35
2.4	Baseline Scenario	50
2.5	Additionality	83
2.6	Methodology Deviations	88
3	Quantification of GHG Emission Reductions and Removals.....	88
3.1	Baseline Emissions	88
3.2	Project Emissions.....	128
3.3	Leakage.....	133
3.4	Summary of GHG Emission Reductions and Removals.....	137
4	Monitoring	140
4.1	Data and Parameters Available at Validation	140
4.2	Data and Parameters Monitored	146
4.3	Description of the Monitoring Plan	148
5	Environmental Impact	157
6	Stakeholder Comments.....	158
7	ANNEXES.....	159

1. PROJECT DETAILS

1.1 Summary Description of the Project

The Ankeniheny-Zahamena Corridor (CAZ) has long been regarded as one of Madagascar's top conservation priorities and numerous studies have catalogued its rich biodiversity. To date over 2,043 species of plants have been identified (85% are endemic), with representatives from five endemic families. Fifteen species of lemurs and thirty other species of mammals are known from CAZ, as well as 129 species of amphibians and 89 bird species. CAZ's flagship species include several species of threatened lemur such as *Indri indri*, *Varecia Variegata variegata*, and *Propithecus diadema*.

The CAZ carbon project covers 370,032 hectares of Madagascar's eastern humid rainforest and provides important ecosystem services to both the surrounding area and greater region. It protects the headwaters of eight large rivers that directly supply approximately 325,000 residents with water. Through dams and aquifers, they also provide water to the residents of the capital city, Antananarivo, and the provincial capital, Toamasina. Water provision and erosion control are particularly important for the agricultural plains to both the east and west of the corridor, and to the two hydroelectric plants that supply electricity to Madagascar's two largest cities. In addition, the forest band located between 600 and 1,200 m probably also plays an important role in the regulation of the local climate. Residents rely on the forest for a range of products, including building materials, food and medicinal plants. The culture of the local people is strongly bound to the forest, which harbours sacred sites, such as tombs.

By far the greatest threat to the forest corridor in terms of forest loss is slash-and-burn agriculture and this threatens the long term existence of the corridor. If this pressure is not alleviated, CAZ will soon disappear and with it the incredible biodiversity it houses, but also the essential ecosystem services it provides to countless rural families in the area.

In order to reduce deforestation in CAZ, the Government of Madagascar and Conservation International developed the strategy of establishing an avoided deforestation carbon project that would provide direct incentives and alternative livelihood activities for communities living around the forest corridor. These discussions resulted in the Government of Madagascar applying to the World Bank BioCarbon Fund for support in 2004. As part of this strategy, CAZ has been included as a new protected area in the country's plans for an expanded protected area system (SAPM – Système des Aires Protégées de Madagascar).

This Project Description describes activities leading to Reduced Emissions from Unplanned Deforestation in the Ankeniheny-Zahamena Corridor (CAZ) project area.

The project aims to reduce deforestation of primary Malagasy forest by creating a corridor to protect the remaining native forests between the Zahamena National Park and the forests collectively known as "Ankeniheny" in central eastern Madagascar (see Figure 1). In addition to protecting forest and stocked carbon, CAZ will protect one of the planet's most important sites for biodiversity conservation and provide a protected biological corridor that links 3 existing protected areas: Zahamena national park, Manongarivo special reserve and Mantadia national park. These parks are at the core of the remaining fragments of the eastern Malagasy rainforest, are extremely rich in terms of biodiversity, and continue to be severely threatened by deforestation. The carbon project is made up of the CAZ protected

area and some areas of forest that are contiguous with the protected area and managed by the same communities that are involved in the protected area management.

The protected area at CAZ has been developed based on an entirely new model for Madagascar that involves a strong collaborative management (comanagement) component with local communities. The proposed protected area will be a “reserve des ressources naturelles” under the Malagasy protected areas legislation (COAP – Code des Aires Protégées), which is equivalent to a category VI protected area under the World Conservation Union (IUCN) classification system. Creation of this new protected area has involved an unprecedented level of stakeholder involvement and consultation for a Malagasy protected area.

The CAZ partners (the Ministry of Environment and Forestry and its regional representatives, Conservation International, regional government authorities, local NGOs, community associations, and other stakeholders) are working to finalize the protected area creation process and to ensure that CAZ is conserved in perpetuity. CAZ is well on its way to becoming one of the largest protected areas in the country and first received provisional protected status on December 30, 2005. This provisional protected status was subsequently renewed in 2008 and again in 2010. Final gazettelement into the protected area system is planned by the end of December 2012. In 2011, the government formally designated Conservation International as the overall manager of the site for an initial period of 3 years during which CI will reinforce the management capacity of the local community structures and other stakeholders involved at CAZ.

Ensuring that the carbon project is in place and providing a sustainable funding mechanism for protection activities is an essential part of the strategy for the protected area. Through the creation of the new CAZ protected area, the project will result in reduced emissions from deforestation. Through the Verified Carbon Standard (VCS), the project will generate Verified Carbon Units (VCUs). Revenues from the sale of these VCUs will be used by the GoM to finance the long term management of the protected area and to expand economic opportunities for local communities.

CI Madagascar has supported CAZ, particularly in the design and implementation of the activities aimed at reducing deforestation, calculation of the emissions baseline and the design of the management plan for the protected area. The World Bank’s BioCarbon Fund has given technical support to develop a Verified Carbon Standard methodology appropriate for CAZ and have signed an Emissions Reduction Purchase Agreement with the Government of Madagascar to buy the initial VCUs generated by the project.

CAZ Protected area Localization map

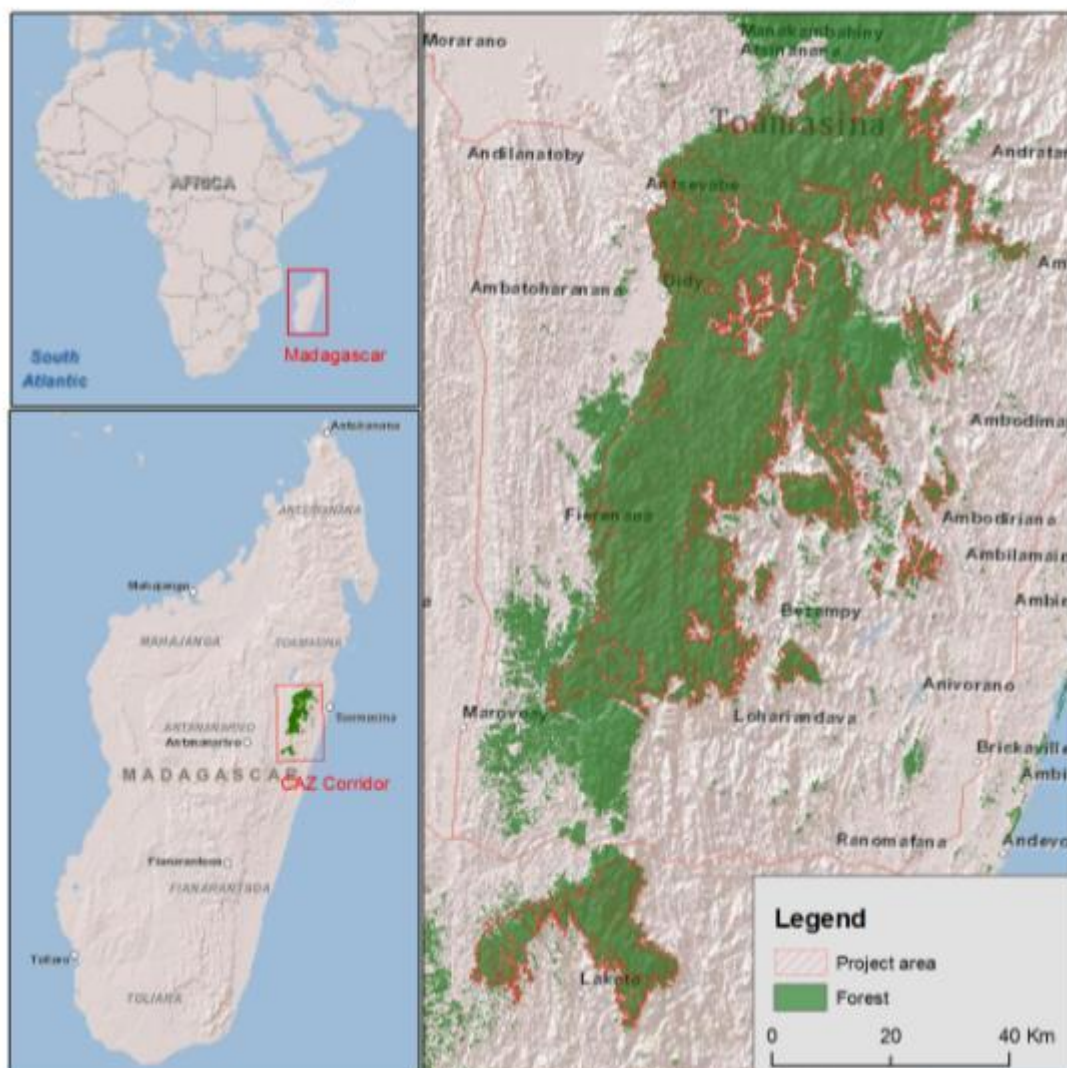


Figure 1. The Carbon Emissions Reduction Project in the Corridor Ankeniheny-Zahamena (CAZ) Protected Area, located in the central eastern forests of Madagascar

1.2 Sectoral Scope and Project Type

The project falls under scope 14 of the VCS, namely Agriculture, Forestry, and Other Land Use (AFOLU). The AFOLU project category is Reducing Emissions from Deforestation and Forest Degradation (REDD). The REDD project activity type is Avoided Unplanned Deforestation (AUD), since the land in the project area is not legally authorised and documented to be converted to non-forest in the baseline (for further details, see also section 2.2). This is not a grouped project.

1.3 Project Proponent

The project proponent is the Government of Madagascar, through the Ministry of Environment and Forests (MEF) represented by the Direction Générale des Forêts (DGF), having overall control and responsibility for the implementation of this project.

Contact information
Director General
Direction Generale des Forêts
Address: B.P. 571 Ampandrianomby, Antananarivo 101, Madagascar

1.4 Other Entities Involved in the Project

Management of the protected area with the objective of reducing deforestation has been delegated by the DGF to Conservation International. CI will play this role of coordinating management activities until December 2014 with the possibility of extension. In addition, CI is the main project developer, providing technical and financial support to the project development and implementation, and is responsible for carbon monitoring. The protected area is collaboratively managed (co-managed), with village level associations and federations of these groups playing an important role in implementing activities. This co-management structure will stay in place for the whole crediting period although the organization responsible for overall coordination (the role currently played by CI) may change during that period.

Contact information
Léon Rajaobelina, Regional Vice President
Conservation International, Madagascar Country Program
Address: B.P. 5178. Explorer Business Park, Batiment C2, Village des Jeux, Ankorondrano, Antananarivo 101, Madagascar
Tel: +261 (0)20 22 60979

No other entities play a major role in the project management. Many community-based organizations are involved in the conservation activities at the field level. The CAZ management structure detailing roles and responsibilities of each institution involved is described in section 1.8 of the PD.

1.5 Project Start Date

The project start date is December 30, 2007. Although the CAZ protected area was first given provisional protected area status by the government of Madagascar on 30 December of 2005 following a project design and regional consultation process that started in 2004, activities to reduce deforestation only started at the end of 2007. This represents the date that the public consultations with local communities on project boundaries and regulations related to forest

use were completed, activities to improve forest management and enforce forest protection began and activities to promote alternatives to slash and burn began. The project start date is therefore taken as December 30, 2007. The choice of this date allows for 2008 calendar year to be considered the first year of the project.

Following the provisional protection status that was promulgated through an executive order in December 2005, a communication and public consultation process was started to determine the details of the project design and governance for the project. The activities to reduce deforestation started at the end of this public consultation process. The chronogram of the main activities of the project are summarised in the following table. Sources of information related to each of these activities are also listed and are available on request by the validators.

Year	Activity	How it addresses drivers of deforestation
2005	Initial project design activities, biological and socio-economic inventories and public consultations with regional authorities and government services that resulted in the Provisional protection status.	These activities did not directly address drivers of deforestation. These were preparatory activities to build local government support and start to include local stakeholders in the project design. The provisional protection status served to communicate the intent of developing the project in the CAZ region. Source: Project reports and documents prepared to obtain the provisional protection status.
2006	Communication campaigns about the this protection status and sensitization on activities to be carried out in a protected area management	This activity did not directly address the drivers of deforestation but prepared local people for the public consultation process. These activities drew attention to the need and the reasons for protecting CAZ and provided an explanation of the project. Source: Communication campaign reports
2007	Public consultations at commune and village levels to define protected area boundaries, zoning and land-use planning	The completion of the public consultation process signals the start of the activities to reduce deforestation because it was through these village meetings that agreement was reached with communities on the need to tackle deforestation, the principles for forest use were agreed and zoning of local areas was agreed. The final consultation meeting was completed in December 2007. Source: Maps, consultation decisions and meeting minutes from community meetings
2007	The NODE small grant program for communities living around CAZ was started. Small grants provide opportunities for funding	Projects funded through the small grants program provide alternative options to previous slash and burn of primary rainforest. Income generating

	sustainable livelihood activities as accompanying measures to conservation activities. Types of projects funded include: Tree nursery establishment for restoration or wood lots, Agroforestry – fruit garden - under cover crops, introduction of new crops, trainings in agricultural techniques, income generating projects. The first grants to communities were for projects completed in late 2007.	opportunities that can be initiated with these grants provides incentives for conservation. Source: NODE grants program reports
2008-2012	Establishing and supporting transfer of forest management contracts for local communities. A variety of activities have been undertaken to establish and improve community management of forests within the project area. These include communications campaigns on management transfer contracts, organizational capacity building of community forest management bodies, trainings on law, development of simplified management plans, (forests inventory, defining boundaries and zoning, land use planning, “cahier de charges”...). Establishing and signature of contracts between the forest service and the community, monitoring of the contract/ local management.	Transfer of management responsibilities to the local communities provides them rights and responsibilities related to access to forest resources, clarifies rules related to forest resource use and provides a formal basis for community organisations to be involved in the co-management of the protected area/avoided deforestation project. Enforcement of forest protection is strengthened through these local management arrangements. Source: Transfer of management agreements
2007-2012	Participatory Ecological Monitoring activities through Conservation Incentive Agreements. Conservation agreements provide direct payments to individuals working on conservation and monitoring activities and community benefits through development projects chosen by the communities. The first tests of these conservation agreements started in late 2007 and additional agreements have been put in place since that time.	Conservation agreements with communities provide incentives for conservation and participatory monitoring activities. These agreements help to make local management activities, particularly surveillance patrols and monitoring of biodiversity and threats to be more effective. Source: Project reports, Conservation Agreements
2008-2012	Enforcement by local authorities, particularly the Forest Service	Following the end of the public consultation process, enforcement of protected area rules has been enforced by local authorities and forestry agents responding to threats reported by local communities and NGOs involved in the project. Source: Forest control reports from the

		forest service
2008-2012	Supporting the establishment and training of federations of community based forest management bodies. The federations are an integral part of the management structure of the project and are taking on an increasingly important role in project management as their capacity increases. Activities with federations include trainings on organizational issues and technical issues so that they can better support the local community forest management bodies in their conservation and monitoring activities.	The federations play an important coordination role in all the activities of the project at the local level. They are increasingly taking on a supporting role for the local management groups and play a regional advocacy and communication role for the project. Source: Federation Activity reports

1.6 Project Crediting Period

The crediting period described in this document begins on the 30 December of 2007, and ends on December 29, 2037, representing a length of 30 years. The crediting period will be renewed twice to a total of 90 years.

1.7 Project Scale and Estimated GHG Emission Reductions or Removals

The implementation of the project will bring about an estimated 10,119,729 tonnes of CO₂ equivalent in emission reductions (tCO₂e) over the first 10 year fixed baseline period. This equates to an average 1,011,973 tCO₂e emissions reductions per year and the project is a Large project (>300,000 tCO₂e/year).

Project	
Large project	✓

The estimated average annual GHG emissions reductions generated by CAZ (after accounting for leakage and prior to buffer withholding) are presented below in Table 1. Since the first baseline period is ten years, GHG benefits are shown until 2017.

Table 1. Summary of ex-ante estimated GHG emission reductions for CAZ

Project Year	Estimated GHG emission reductions or removals (tCO ₂ e)
2008	111,993
2009	239,465
2010	422,868
2011	596,188

2012	693,005
2013	1,328,143
2014	1,493,267
2015	1,523,275
2016	1,730,772
2017	1,980,755
Total estimated ERs	10,119,729
Total number of crediting years	10
Average annual ERs	1,011,973

1.8 Description of the Project Activity

The strategy for the project activity is the creation and implementation of a protected area that encompasses the project area. CAZ is equivalent to an IUCN category VI protected area¹ - an area managed mainly for the sustainable use of natural resources (a *Réserve de Ressources Naturelles* in Madagascar's national legislation). The creation, management and zoning of the protected area are presented here. The fundamental hypothesis for this project is that local forest-stakeholders must gain a net benefit from the implementation of the protected area if it is to stop deforestation. To achieve this, the project is using the protected area as a framework to provide local people with improved rights over the use of the forest resources in community use areas, viable alternative livelihoods to deforestation, and will use carbon revenues to pay local people to work on the conservation of the area. These combined activities are intended to encourage more productive land uses over the medium and long term.

The principal cause of deforestation is *Tavy* (slash-and-burn cultivation): the combination of a co-managed, multiple-use protected area with the suite of development actions will reduce *Tavy* and effectively address the key cause of deforestation.

Protected area creation

To ensure ownership of the conservation process, a participatory approach was adopted for the creation of the CAZ protected area. Stakeholders such as ministerial representatives, civil society groups, local authorities, and community-based organizations participated in the sequence of steps that led to the establishment of the protected area.

Initial Scientific and Technical Planning Workshop

In February 2005 a first planning workshop with biologists, foresters, and sociologists who had conducted research in CAZ was held to ensure that the scientific basis for establishing CAZ as a protected area was solid. This workshop resulted in an initial proposal for the CAZ boundaries that was largely based on biodiversity value. This initial proposed boundary remains very similar to the final protected area limit that has been agreed upon following the public consultation process.

¹ IUCN definition: "Category VI protected areas conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area."

Provisional Protection Status

The initial proposed protected area boundaries were the foundation for negotiations that were held with representatives of the district and communes. The result of these negotiations included a new map of the protected area and an overall land-use plan for the area, which were presented at meetings in all three administrative regions that were initially included in the project area. Subsequently, a declaration in support of the creation of the CAZ protected area was signed by the Président de Délégation Spéciale de Toamasina, the three regional Heads, the Director of the Directorate responsible for forests, and the Plate-Forme du Corridor Ankeniheny Zahamena (PlaCAZ – a platform representing civil society organizations) on 20 December 2005. These documents formed the dossier that was submitted to the Directorate of Protected Areas for temporary protection status, which was awarded on 30 December 2005.

Definitive Protection Status

To achieve definitive protection status, CI Madagascar first worked with various stakeholders to produce a series of high resolution maps (1/50,000) that include landmarks and topography. These were used for local consultations aimed to consult with local communities about the protected area creation process and gather information about their needs and concerns. Consultations were held in all of the communes affected by the protected area over two years (2006 – 2008). They resulted in updated maps with communal zoning of land uses that took into account the present and future land and natural resource use of local people. The results of the consultations were integrated in the protected area management plan that was finalised with the stakeholders in March 2009. An important difference between the limits of the protected area after the 2005 temporary protection and the final proposed protected area limits is that only two administrative regions are included in the final protected area.

Between April and December 2010, CI Madagascar and partners completed a detailed social impact assessment of the protected area. The study also consulted each community impacted by the protected area following the World Bank's Operational Policy 4.12 on social safeguards². This was used to define the social safeguard plan that identifies mitigation measures needed to ensure that no households are negatively affected by the project.

Reports detailing the establishment of the protected area (including the protected area management plan, its delimitation, the social and environmental impact assessment and the development of social safeguards) are available to the validator on request.

Goals of the Ankeniheny-Zahamena Corridor Protected Area

The objectives of the project are to reduce deforestation through the creation and management of a comanaged protected area and financed by revenues from the sale of carbon emissions reductions. Through the protected area the project aims to reduce greenhouse gas emissions, enhance the wellbeing of resident communities through sustainable livelihood development, to conserve biodiversity, to maintain ecosystem services and to enable the sustainable use of natural resources by local residents.

² OP 4.12 defines involuntary resettlement to include loss of access to natural resources; the project did not lead to any physical relocation of households or to local people being deprived of traditional land.

To ensure that forest stakeholders benefit from the establishment of the protected area, the management plan includes measures such as:

- Promoting farming alternatives to slash and burn agriculture (*Tavy*);
- Providing technical support for improved agriculture
- Constructing of small irrigation and drainage systems for agriculture
- Establishing new revenue-generating activities that don't cause deforestation (ecotourism, nursery management for reforestation activities, fishing, etc.)
- Marketing the products of revenue-generating activities;
- Streamlining of the management transfer process for natural resources (community management of forests)
- Supporting communities to establish partnerships and funding for development projects.

Governance structure

The management strategy prioritizes improving human livelihoods and includes many targeted actions to ensure that CAZ produces real benefits for those people who rely on its resources. These actions are grounded in the CAZ collaborative governance structure, which serves as the overarching framework for sharing management responsibilities and distributing benefits.

CI Madagascar supported a series of consultation meetings to determine the final governance structure of CAZ. Stakeholders at multiple levels participated, including local communities, the Ministry of Environment and Forests (MEF) and its regional representatives, regional authorities and local NGOs. The decision was made to adopt a collaborative management (co-management) governance type, with an emphasis on community-level participation and empowerment.

The co-management structure of CAZ comprises the Ministry of Environment and Forests (MEF) who have overall responsibility, a delegated manager responsible for the day-to-day coordination of all management activities and then "local management units" that are community-run associations responsible for management of a particular part of the project area. Due to the number of local management units involved, these have been organised into federations responsible for specific geographic areas referred to as sectors. In addition, an Orientation and Monitoring Committee with members from government services and other stakeholders serves as an oversight body and a consultative organ to ensure that the project is well integrated within the regional development context.

The CAZ manager and its staff, six sector managers at the community federation level and the community associations are directly responsible for the management of the protected area. The delegation agreement between the Ministry of Environment and Forests and the delegated manager also allows for subdelegation of the overall management responsibility for a specific area if there is a more appropriate partner for it. Specific roles and responsibilities of each of the entities are described below and illustrated in Table 2

- The ultimate decision making body is the MEF; it has the final say on the management of CAZ, approves the protected area management plan, annual workplans and annual reports. The MEF can also act at any level of the protected area through its decentralized representatives at regional and local levels and is ultimately responsible for law enforcement.
- The Orientation and Monitoring Committee serves as a consultative body that provides guidance on policies of the protected area and its management.

- The delegated Protected Area Manager ensures the executive function of the entire protected area. Presently, CI Madagascar is fulfilling this role and has a management contract with the government. The Manager is responsible for all aspects of the protected area management, compiling reports from the Sector and Local Management Unit (LMU) levels, and reporting to the MEF and Orientation and Monitoring Committee.
- A total of six management sectors have been defined for CAZ (illustrated in Figure). Each sector coordinator supervises the Local Management Units and liaises with the manager, the authorities and partners within the sector. The sector coordinator is designated by the community federations.
- The Local Management Units are at the most local level within the management structure. They are responsible for the community management of specific areas which are often, but not necessarily, formally defined through renewable natural resource management contracts (*Contrats de Transfert de Gestion*). As part of the project activities, the various forms of agreements that currently exist will be standardized following policy that is being developed for new protected areas. At the time of submission of this PD, it is envisaged that these agreements will take the form of “Contrat de Gestion Communautaire” signed between the manager and the Local Management Units. The LMUs may also use traditional by-law agreements known as *dina* to enforce local rules.

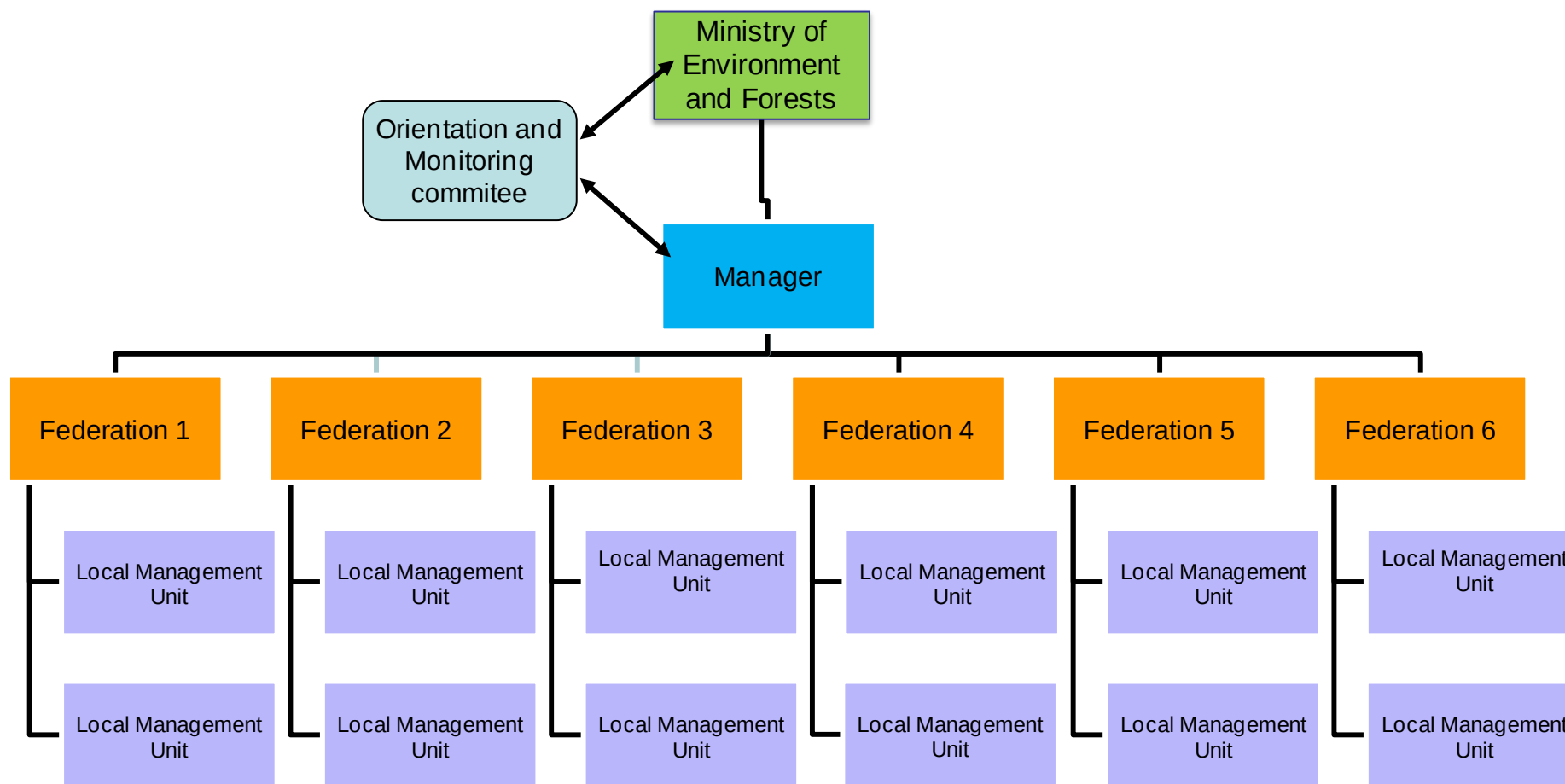


Figure 2. Schematic representation of the co-management structure for CAZ

Table 2. Roles and responsibilities of the members of the CAZ co-management structure

Structure	Composition	Roles and Responsibilities	Decision making process
Ministry of Environment	Ministry represented by the <i>Direction Générale des Forêts (DGF)</i>	Liaise with other ministries, and technical and financial partners Approve management plan Support the Manager on legal issues, administrative issues and law enforcement Approve annual workplans and reports	The ultimate decision maker for the management of CAZ
Orientation and Monitoring Committee (OMC)	2 DREF (Forestry Directors for the Regions) 2 Regional Heads 1 PA manager representative Designated representatives: 2 other regional ministerial representatives 2 sector representatives 2 mayors (1 per region) 2 civil society (including 1 from the PlaCAZ platform) 2 technical and financial partners	Endorse orientations and strategies for implementing management Monitor and evaluate technical, administrative, and financial management of PA Monitor management implementation by the PA Manager Analyse policy implementation and suggest new orientations Advocacy	Advise / guide the PA Manager Serve as deliberating and consultative body Deliberating - management plan implementation Consultative - policy, general strategy and orientation Meets twice a year Approves work plans and reports
Protected Area Manager	Head of the CAZ protected area and associated staff	Develops strategies for management implementation Update management plan Implement management plan and develop annual work plans Monitor and evaluate achievements vis-à-vis management plan Interface with stakeholders Orientate and support activity implementation at the Sector level Develop business plan and fundraise Approve the management plans of the Local Management Units	Receive reports from Sections Submit reports to OMC and GoM Communicate action plans for management with the sections Accountable to Ministry

Structure	Composition	Roles and Responsibilities	Decision making process
Section Coordinators	Section Coordinator employed by the PA Manager (in the long term by the federations).	Collect and analyse Local Management Unit reports Supervise management by Local Management Units (LMU) Submit reports to regional ministry representatives Liaise with local authorities	Reports to PA Manager Compiles reports from LMUs Platform: 1 commune rep. 1 partner rep. 1 rep. per LMU
Local Management Unit (LMU)	Stakeholders including local community associations, partners	Develop and implement LMU management plan Conduct patrols of the strict conservation zone near LMU Represent the community within the PA governance structure Manage LMU (Dina, reporting)	Report to Section Coordinator Decision making within the General Assembly

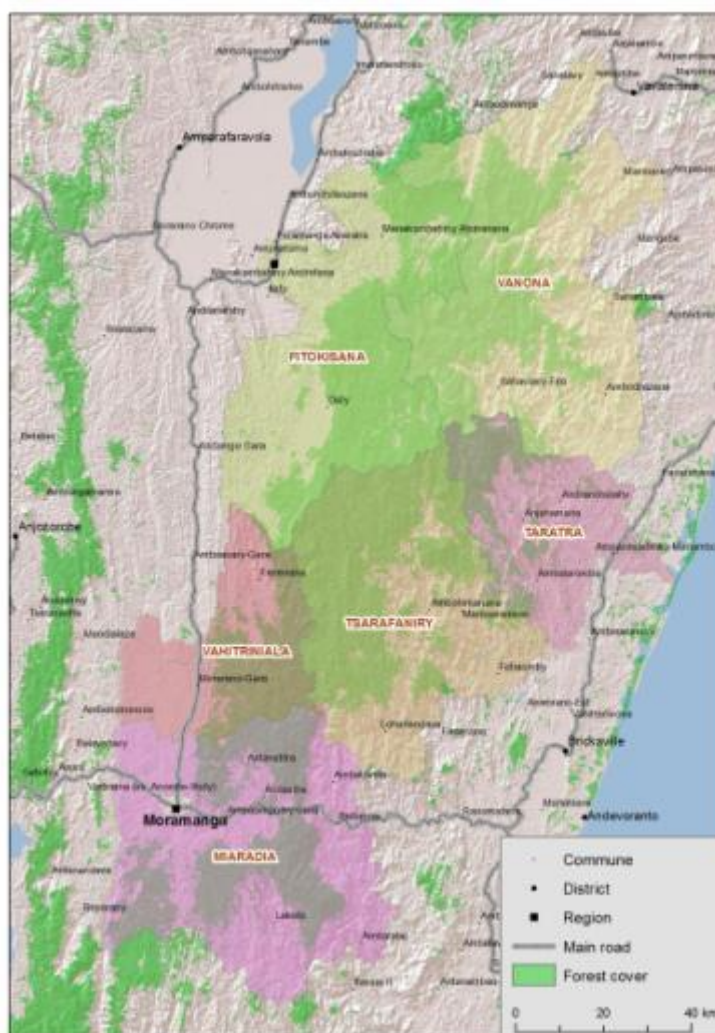


Figure 3. The six management Sectors of CAZ

The protected area makes up the foundation of the VCS project area. Areas of forest managed by local communities that are contiguous with the protected area are also included in the carbon project area as project activities occur in these forests too. The following section presents the zones of the protected area and the community areas that make up the VCS project area.

Zoning of the protected area

In order to conserve the natural forest while supporting the sustainable development of the local people, CAZ is divided up into different management zones. These are presented in Table 3 and Figure. There are two main management areas: a strict conservation zone, and a surrounding buffer zone.

1. The **strict conservation zone** constitutes the inner sanctuary of the protected area and encompasses the areas of key conservation value. All activities and entry to the area are strictly regulated. This area is largely under the direct management of the delegated protected area manager, but also includes some forest areas that are community-managed. No people live in the strict conservation zone.

2. The **buffer zone** is comprised of settlement enclaves and sustainable use zones. It includes forest and non-forest land.
 - a. **Settlement enclaves** are areas of traditional settlement / farming which are surrounded by the strict conservation zone and were frequented before the creation of the protected area. Here the resident populations will remain living and farming as they did before the creation of the protected area.
 - b. The **sustainable use zone** surrounds most of the strict conservation zone and separates it from the areas peripheral to the protected area.
 - i. It is largely comprised of sustainable use forest, which local communities will use to meet their subsistence timber, non-timber forest products and fuel wood needs according to quotas defined in their community management convention. The level of harvesting will be sustainable and the forest will be maintained over the long term.
 - ii. Restoration areas, where natural forest will be restored to establish full ecosystem functioning.
 - iii. The sustainable use area also includes service areas that are planned for tourist, education and protected area infrastructure.

Communities neighbouring the sustainable use zone manage it under renewable natural resource management contracts with the government of Madagascar. These community managed areas extend around the entire protected area (Figure 5). The extent of the community-managed areas is well defined in the natural resource management contracts. They extend from within the protected area boundary (the sustainable use zone, as well as some parts of the strict conservation zone) to traditional community lands that are outside of the protected area.

The delimitation and zoning of the protected area was done according to Malagasy law with the full consultation and participation of the local communities. The zoning takes into account the local communities' customary use of forest and land, as well as their expressed needs of forest resources over the next 50 years. The lengthy consultation on the delimitation and zoning of the protected area, together with its formal validation by the resident people, ensures that there are adequate land and forest resources for the resident communities.

Table 3. Correspondence between protected area zone and VCS spatial boundaries

Zone	Corresponding VCS spatial boundaries	Area (ha)
Protected Area		
<i>1. Strict conservation zone</i>		
Strict conservation zone	Project area (Cat. A)	234,165
<i>2. Buffer zone</i>		
Sustainable use forest	Project area (Cat. B)	112,316
Settlement enclave	Leakage management areas	178,428

Zone	Corresponding VCS spatial boundaries	Area (ha)
Managed Forest areas contiguous with the Protected Area	Project area (Cat. B)	23,552
Non-forest land within 2km of project boundary	Leakage management areas	45,942

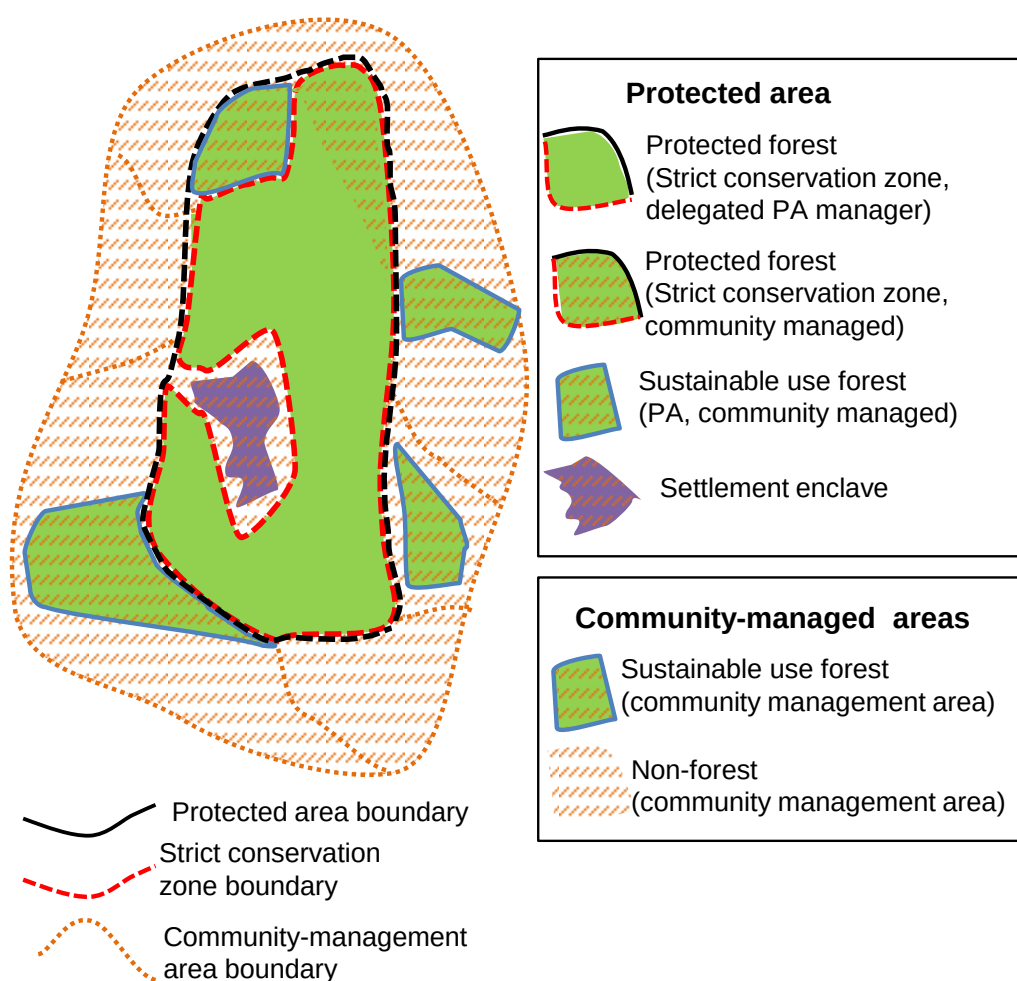


Figure 4. Simplified representation of the zoning of the CAZ protected area

Community Forest Management

As noted in the description of the zoning of the protected area above, the management of the buffer zone of the protected area will be transferred to the local communities through natural resource management contracts. The delineation of some of the management contract areas is still under way.

The community management contracts are based on the 2001 “Gestion Contractualisée des Forêts” legislation that provides the basis for community-based management of natural

resources. The project makes use of two instruments based on this law, namely *Gestion Locale Sécurisée* (GELOSE) and *Gestion Contractualisée des Forêts* (GCF).

In 1996, the Government of Madagascar passed legislation (Loi No 96-025) establishing the authority to devolve natural resource management control to local communities. This legislation (*Gestion Locale des Ressources Naturelles Renouvelables* - GELOSE) has permitted a process, referred to as *Transfert de Gestion des Ressources Naturelles Renouvelables* or simply *Transfert de Gestion* in the legislation, that allows for the delegation of limited tenure and sustainable use rights to a legally recognized local community institution (*Communauté de Base* - COBA), in exchange for a contractual obligation with the Government of Madagascar to conserve the transferred natural resources. The transfer of management rights of natural resources is for a defined period. The 1996 legislation was amended in 2001 to allow for forest specific community management contracts (*Gestion Contractualisée des Forêts de l'Etat* (GCF)). The *Communauté de Base* (COBA) must be a legally recognised community association with an 'elected' management committee (*Comite de Gestion* (COGE)) – which signs time bound contracts with the forest service to take charge of forest management.

The project has made use of GCF transfer management contracts for natural resource management to the local communities. The limits of the management contracts, the land-use within the community management area and the rules governing the management of the natural resources are defined by the community themselves and formalised in the management contract.

Building successful partnerships is a cornerstone of the approach. To work effectively in three regions, over twenty communes, and countless villages, CI Madagascar has partnered with local NGOs, other donor-funded projects, the private sector, and community associations. This tactic, which is the foundation of the successful model that CI has adopted for Madagascar, has allowed us to expand our reach to the entire CAZ corridor.

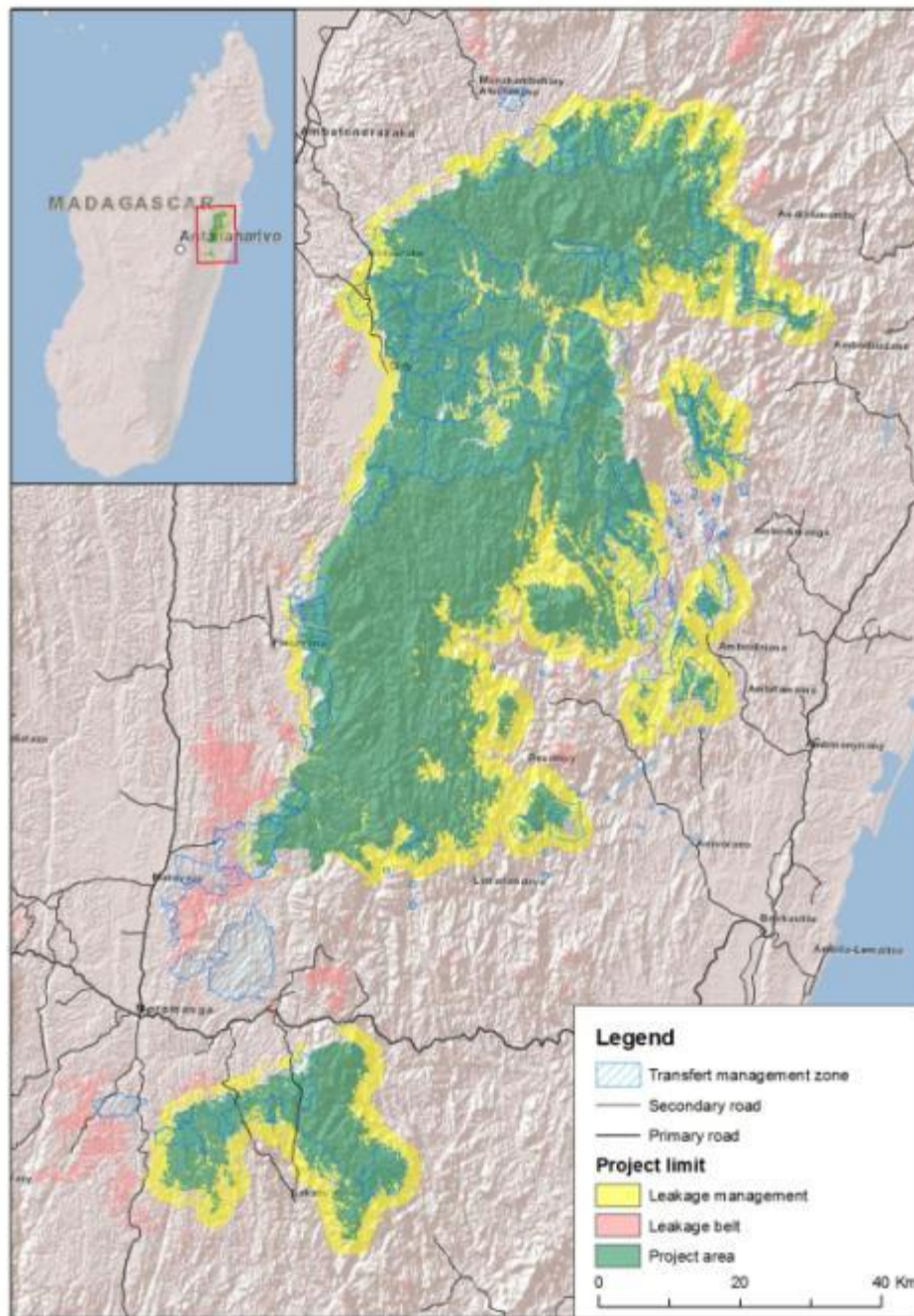


Figure 5. Areas for community management that have been identified to date in the protected area

Conservation agreements

Conservation agreements are a key part of the project's approach. The agreements are established between CI Madagascar and local communities of CAZ with the support of governmental authorities. The purpose is to engage communities in a commitment to achieve measurable forest conservation results while offsetting the forgone benefits that they would have otherwise gained from use of the forest.

The conservation agreements are established with the involvement of the respective Local Management Units of CAZ's governance structure so that there is a direct link between the conservation actions communities perform and the overall management of the protected area. Indicators of natural resource management effectiveness and the status of threats and conservation targets are tracked. The information generated provides information on local biodiversity, threats and land-cover changes. Community members involved in collecting data gain through direct employment and the wider community benefits from micro-development projects that they define on annual basis. Key to the success of this approach is that communities choose incentives that best meet their development needs, but priority is given to activities related to sustainable livelihoods.

Small grants

Another means that the project is using to create economic opportunities for local people and so reduce deforestation in CAZ is through its Small Grants Programme. Here the project provides grants to local community associations so that they are able to undertake activities that provide income and also contribute directly to forest conservation outcomes. As CAZ's governance structure becomes more robust, the project is prioritizing LMUs to receive this funding.

The Node Small Grants Programme uses an innovative mechanism to disburse funds. Rather than centralized grant-making controlled by CI Madagascar employees, the project has partnered Malagasy NGOs – the “Nodes” – working in district-level towns to receive and review proposals, issue grants, and monitor activities. CI Madagascar has provided strong technical support to these local partners. This mechanism provides these Malagasy NGOs with an opportunity to build their grant management skills, as well as build their expertise in supporting conservation.

Fire alerts and real-time monitoring of forest loss

The University of Maryland, NASA and CI run a MODIS satellite based fire monitoring system which provides daily fire alerts for the project area. This enables the timely location of fires from slash and burn agriculture in forest areas. CI has also developed an approach to regularly monitor forest loss from Landsat imagery. This will be developed as a near real-time monitoring and adaptive management tool as part of the project.

Step VM 03 “Analysis of agents, drivers and underlying causes of deforestation” presents the causal analysis of deforestation and how the project measures are designed to address each of the underlying causes of deforestation.

The implementation schedule of these project activities follows an adaptive management strategy by which activities are planned and decided each year on a participatory basis amongst all involved stakeholders. A projection of the project's implementation schedule is included in the CAZ financial plan.

1.9 Project Location

The project is constituted by the CAZ protected area and the adjacent community-managed forests, located in the center of Madagascar's eastern slope rainforests in the Province of Toamasina (Figure 1). It is broadly delimited by the Zahamena National Park (center: 17°40'S, 48°50'E) to the north and the Ankeniheny Classified Forest in the commune of Lakato to the south. The precise boundaries of the project area are defined by the limits of the protected area, and the limits of the community management forest areas. GIS and KML files of the project boundaries are available to the validator. The separate parcels' ID, coordinates of centroids, area and land tenure status are presented in Annex 3.

The project area covers 370,032 hectares and is entirely owned by the Government of Madagascar. It is found within the regions of Alaotra-Mangoro and Atsinanana; and the districts of Ambatondrazaka, Moramanga, Brickaville, Toamasina II and Vatomandry. The administrative areas encompassing the project are summarised in **Error! Reference source not found.**Table4.

Table 4. Administrative areas in which the project is located

Région	District	Commune
Région Alaotra-Mangoro	District d'Ambatondrazaka	Didy
		Manakambahiny-Est
		Feramanga-Nord
		Ambatondrazaka II
	District de Moramanga	Fierenana
		Morarano
		Ambohibary
		Ampasimpotsy-Gare
		Lakato
		Andasibe
		Beforona
		Ambatovola
Région Atsinanana	District de Brickaville	Loharindava
		Andekaleka
		Ambohimana
		Maroseranana
		Fetraomby
		Anjahamana
		Ambalarondra
	District de Toamasina II	Ambodilazana
		Mangabe- Antenina
		Fito
		Sahambala
		Andranobolaha
	District de Vatomandry	Ambalabe

1.10 Conditions Prior to Project Initiation

Communities and economic activities

The rural communes surrounding the corridor have a total population of approximately 325,000 inhabitants. The majority of people are rural, subsistence farmers.

The principal economic activity of the region surrounding the corridor is agriculture. Rice is the primary crop, both in terms of the total area cultivated and by value. Secondary agricultural activities include cultivating manioc, coffee, sweet potatoes, bananas and ginger. Small quantities of beans, maize, sugar cane and some vegetables are also grown and small animal husbandry is practiced by less than a third of the population with chickens, some cattle and pigs. Cattle rearing are much less predominant than in the highlands or west of Madagascar due to the lack of good pastureland. Extensive slash-and-burn (*Tavy*) is the main traditional agriculture system and is the greatest threat to the surrounding forests.

The isolation of many of the communities has a significant impact on the local rural economy and on agricultural activities. The lack of road infrastructure strongly limits economic development. In various communities located around the Corridor (such as Manakambahiny East, Antenina, Fito, Maroseranana, and Ambohimana), it is difficult to promote commercial agriculture because of the inherent difficulty of transporting goods to market. Most of the population therefore practises subsistence farming.

Aside from agriculture, small-scale logging, charcoal production (in areas close to the national road), mining (in the eastern areas), daily manual labour, and small-scale commerce make up secondary ways of earning money in the surrounding communities. Basket weaving and carpentry also bring income to some families. Lumberjacks are especially present in the Anjahamana, Andanobolaha, and Didy zones.

The Corridor has mineral resources (such as gold and quartz) which are sometimes illegally exploited on a small scale. Nickel and cobalt in the Ambatovy-Analamay Forest are mined by the Ambatovy Company on an industrial-scale outside the project area. An old graphite mine exists in the Andasibe commune, again outside of the project area, but is not currently in use.

Impact of *Tavy*

Tavy (slash-and-burn cultivation) is the principal form of cultivation in the area immediately surrounding the CAZ project, as it is in much of the country. Subsistence farmers practise *Tavy* because of topographic constraints, the low labour and monetary input required relative to returns, and tradition. Over several decades, the practice of *Tavy* leads to a succession of vegetation types with decreasing biomass. Immediately around the project area, farmers come back to use the same fields in cycles of less than 10 years and this leads to a slow decrease of biomass in the fallow vegetation and reduction of the soil fertility. After several *Tavy* cycles, the fallow vegetation is typically dominated by non native invasive plant species such as *Psiadia altissima*, *Rubus moluccanus* and *Lantana camara*, grasses and ferns. The frequent use of fire favours exotic, aggressive species over native species. Once these invasive species have dominated, natural regeneration back to forest does not occur even after several decades. The soils of these areas become less fertile and result in poor rice yields, thus increasing pressure to abandon land and clear new forest for agriculture.



Figure 6. Typical landscape immediately outside of the project area. Tavy results in deforestation and a mosaic of hill-rice and fallow areas with recovering vegetation.

Malagasy in urban areas are heavily dependent on charcoal for household energy needs. This charcoal is produced from wood which in this CAZ area comes exclusively from Eucalyptus plantations that are outside of the project area.

1.11 Compliance with Laws, Statutes and Other Regulatory Frameworks

The project is in compliance with the national and local laws applicable to the project, notably:

- The Madagascar Environmental Charter;
- The MECIE decree on environmental impact assessment (*Mise en Compatibilité des Investissements avec l'Environnement* (MECIE));
- The Protected Area Code (*Code des Aires Protégées* (COAP));
- The local management of renewable natural resources (*Gestion Locale Sécurisée des ressources naturelles renouvelables* (GELOSE));
- The local management of forest resources (*Gestion Contractualisée des Forêts* (GCF)) – a complement to GELOSE that is specific to forests; and
- Customary local law (*Dina*).

Madagascar Environmental Charter

Madagascar's Environmental Charter was adopted in 1990 (law 90-033). This law defines the 'environment', sets down fundamental principles and responsibilities and identifies the mechanisms for implementation, including establishing the 15-year³ National Environmental Action Plan (NEAP). Article 10 introduces the requirement that projects which could harm the environment should be subject to an Environmental Impact Assessment (EIA), taking account of: the technical nature and scale of project impacts; and the sensitivity of the area in which the project is physically located.

The project contributes towards the objectives of the Environmental Charter through the emphasis on protecting natural habitats, biodiversity, strengthening natural resource governance and contributing towards the socio-economic development of the region around CAZ.

³ Originally planned as 3 phases of 5 years, phases have averaged 6-7 years, resulting in a 20-year programme

MECIE

The procedure for EIA in Madagascar was first laid out in the MECIE decree of 1992 (92-926), revised in 1995 by decree 95-377 and acquired its present form through decrees in 1999 (99-954) and most recently in 2004 (2004-167). In 1997, an inter-ministerial order (4355/97) defining zones to be considered as 'sensitive', and thus subject to mandatory EIA for all investment projects, was issued. 'Sensitive zones' are defined by inter-ministerial Order N° 4355/97 and include coral reefs, mangroves, small islands, tropical forests, areas subject to erosion, areas subject to desertification, wetlands, nature conservation areas, land around drinking water sources and paleontological, archaeological or historic sites. Each of these has a specific definition.

The Order's definition of 'nature conservation areas' is broad and includes protected areas and their designated buffer zones, wildlife reserves and sites of biological interest (including sites already delimited, being delimited, classified or being classified). The criteria for 'biological interest' include the existence of migration corridors, breeding or foraging areas, sites with 'relict' forms or harbouring protected species (Part VIII of order 4355/97). Irrespective of site status, promoters discovering species or sites that meet the criteria for biological interest are obliged to implement immediate conservation measures and to inform the authorities.

The MECIE decree designates the *Office National pour l'Environnement* (ONE) as the sole authority for the screening of new projects, determination of the type of EIA to be conducted (whether full or shorter EIA, or neither of these), evaluation of EIAs, setting norms, thresholds and limits (e.g. on effluent discharges), award or refusal of a 'certificate of conformity' (environmental permit) and subsequent monitoring of the adopted environmental management plan (also referred to as a '*cahier de charges*').

The project is complying with the MECIE through the development of an Environmental and Social Impact Assessment and Management Plan. These have been submitted to ONE for review and approval. The methodology used was consistent with the ONE guidelines for EIAs for protected areas and goes further by adhering to the World Bank's "safeguard" Operational Policy OP4.12 that covers restriction of access to natural resources.

COAP

The *Code des Aires Protégées* (COAP) or Protected Area Law (Loi numéro 2001 - 5 du 11 février 2003 portant Code de Gestion des Aires Protégées), not only describes the various types of protected areas of the Madagascar Protected Area Network (*Système des Aires Protégées de Madagascar* (SAPM)), it specifically prescribes zoning categories that each protected area manager in Madagascar must comply to in the early stages of project identification and implementation. The COAP law also defines a set of governance principles to which the protected area manager must comply. These are:

- The fair distribution of roles, responsibilities and benefits between the protected area manager and the various stakeholders in the creation and management of the protected area
- The systematic consultation and dialogue between the protected area manager and the various stakeholders in the creation of the protected area
- The co-management, notably through the establishment and use of a management plan elaborated with the various stakeholders, as well as a community management agreement as a specific tool for the participation of local communities in the management of the protected area

- The adoption of mitigation measures to offset restrictions on ownership or use induced by the creation and management of the natural resources of the protected area
- Transparency and responsibility of the manager of the protected area vis-à-vis the various stakeholders

The project is in full compliance with the COAP, which has been the guiding legislation during the protected area design and creation process. This is demonstrated by all the official legal texts related to the protection of CAZ, which are based on the COAP. The Arrêté Ministeriel 20.022-2005/MINENVEF formalized CAZ's temporary protection status and described the original protected area zoning, demonstrating compliance to the relevant Malagasy laws and regulations. This Arrêté was subsequently extended in 2008 and 2010 through the Arrêté Ministeriel Arrêté interministeriel 18633/2008 and the Arrêté interministeriel 52005/2010. The most recent version of the planned internal zoning (i.e. taking into account the whole public consultation process) is included in the management plan for the protected area and this will be used for the final gazettelement decree.

Forest Resource Management Transfers

In 1996, the Government of Madagascar passed the law GELOSE 96-025 - legislation that enables the devolution of natural resource management to local communities. The law allows the delegation of limited tenure and sustainable use rights of renewable natural resources to a legally-recognized local community institution (a *Communauté de Base* (COBA)), in exchange for a contractual obligation vis-à-vis the government to conserve the transferred natural resources. Decree 2001-122 governs the implementation of devolved forest resource management to local communities (Decree 2001-122, *Décret fixant les conditions de mise en oeuvre de la Gestion Contractualisée des Forêts de l'Etat* (GCF)). It allows forest specific community management contracts. Under GCF, contracts are signed between the government and the representative of the COBAs, the Community Management Committee (COGE). The request must come from the local community. In 2004, CI began working with the Ministry of Water and Forests and the communities surrounding the CAZ forests to implement community-managed GCF sites within the community use zone of the project area. The CAZ project makes use of the GELOSE legislation in some areas to transfer management rights of forests to local communities.

Customary bylaws (Dina)

Although not an official law, customary bylaws, known as *dina*, are also important for aspects of CAZ's management. Dina are customary rules agreed upon by members of the community. Many of the official rules, for examples those set out in GELOSE/GCF contracts, are transformed into dina at the local, village level.

A complete list of relevant Malagasy legislation is presented in Annex 2.

1.12 Ownership and Other Programs

1.12.1 Right of Use

The Government of Madagascar (GoM) through the Ministry responsible for forests (the Ministry of Environment and Forests - MEF at the time of PD development) is the project proponent and owner of the VCUs generated by the project activity. All the forest in the project area is owned by the Government of Madagascar and the government is responsible for project activities and therefore VCUs generated remain the property of the government. The Government of Madagascar has delegated the project management to CI through a management delegation contract. The delegated project manager and local community associations are all part of the management structure and will therefore share responsibility for deciding how the revenues from the sale of VCUs will be used to achieve the project objectives through the development of annual work plans and budgets that have to be approved by the whole management structure.

Table 5 summarises the land tenure and ownership of the project area, described below:

1. **Protected area:** The protected area is state land with the status of a protected area. Its boundaries have been defined in the protected area management plan based on public consultation and will be recorded in the government cadastral services at the time of permanent gazettelement of the protected area. It is comprised of:
 - a. The project area within the strict conservation zone. The MEF is responsible for the management of this zone and has delegated that responsibility to the protected area manager.
 - b. The project area within sustainable-use forest areas of the protected area. The MEF remains responsible for the management of these zones and has delegated responsibility for management to the protected area manager and community management associations (COBA).
2. **Community managed areas outside of the protected area:** The forest outside of the proposed protected area belongs to the State. Community stakeholders may apply to manage these areas through a GCF "transfer of management" contract. Conservation activities in these areas are an extension of the work inside the official protected area boundaries.

The contract between the GoM and the delegated protected area manager, as well as the GCF contracts between the GoM and the community management associations, are both for fixed terms and their renewal is dependent on performance.

Table 5. Summary of the land tenure and ownership of the project area

Zone	Land tenure	Legal owner	Co-management responsibility
Protected Area			
Strict conservation zone (Delegated PA manager)	State land managed by a delegated PA manager under a revocable, fixed-term agreement	GoM	CI/delegated manager
Strict conservation	State land (PA) managed by	GoM	CI/delegated

Zone	Land tenure	Legal owner	Co-management responsibility
zone (Community-managed area)	community management associations under revocable, fixed-term agreements		manager and Community Associations
Sustainable use forest (Community-managed area)	State land (PA) managed by community management associations under revocable, fixed-term agreements	GoM	CI/delegated manager and Community Associations
Community-managed areas outside the Protected Area			
Sustainable use forest	State land managed by community management associations under revocable, fixed-term agreements	GoM	Community associations

The project proponent therefore has control of 100% of the project area by virtue of the following rights of use (VCS Standard (version 3.2), 3.12.1 Right of Use, paragraph 4):

“A right of use arising by virtue of a statutory, property or contractual right in the land, vegetation or conservational or management process that generates GHG emission reductions and/or removals (where such right includes the right of use of such reductions or removals and the project proponent has not been divested of such right of use).”

The project proponent's right of use is demonstrated by Malagasy law under which all forests other than on private land belong to the State (see section 1.11). No private land tenure exists in the project area.

A benefit sharing agreement for carbon revenues will be established between the project proponent and all legitimate stakeholders in the project. The goal is to ensure an equitable and transparent division of the revenues from sale of the VCUs. Under this agreement, the project will develop sub-project agreements between the project proponent and each of the parties that may have claim to the carbon sequestered due to their contribution to the implementation of the project activity, namely the delegated manager of the protected area and the community management associations. Under the sub-project agreement, the party will cede the rights to all carbon resulting from the project activity to the project proponent. Consequently all VCUs generated by the project activity will be aggregated under the sole ownership of the GoM. Decisions on how the revenues from the sale of VCUs will be used to achieve the project objectives are made through the development of annual work plans and budgets that are approved by the whole management structure.

1.12.2 Emissions Trading Programs and Other Binding Limits

Not applicable. Madagascar has no national or international binding commitments to reduce GHG emissions.

1.12.3 Participation under Other GHG Programs

The project has not been registered under nor is seeking registration under any other GHG program.

1.12.4 Other Forms of Environmental Credit

The project described in this document has not created any other form of GHG-related environmental credit. The project will be validated and verified against the VCS. Therefore the only GHG-related environmental credit generated by the project will be under the VCS Program.

1.12.5 Projects Rejected by Other GHG Programs

The project has not been rejected by any other GHG program.

1.13 Additional Information Relevant to the Project

Vegetation description

At a landscape-level the project area falls within a region that is classified as eastern humid forest (Moat & Smith, 2007 in Atlas of the vegetation of Madagascar, Kew Publishing, Royal Botanic Gardens, Kew). The majority of the project area is mid-altitude humid rainforest with a canopy frequently taller than 25 m at lower altitudes, although forest strata are indistinct. There are small herbaceous wetlands on valley floors. Characteristic canopy genera include *Weinmania*, *Tambourissa*, *Symphonia*, *Dalbergia*, *Ravensara*, and *Vernonia*. The dense understory comprises *smilax*, *cyathea*, etc. with a high diversity of epiphytes, especially orchids.

The project area is made up of intact natural forest. Immediately outside of the project area the land use is a mosaic of fragmented primary forest, eucalyptus plantations, Tavy cropland (including savoka fallows of different ages), some rice paddies in the valley floors, and the villages of subsistence farmers. In the more populated areas repeated cycles of slash-and-burn agriculture have led to the wide-spread occurrence of invasive species in the fallows, such as *Aframomun* spp. and *Lantana camara*, and *Imperata cylindrical*. Subsistence harvesting of timber and collection of firewood from natural forest by rural communities takes place throughout the edges of the corridor. Illegal, small-scale selective logging has historically also taken place throughout the accessible forests included in the reference region.

Relief

The project area encompasses a corridor of humid eastern rainforest that extends in a north-south direction over about 180 km in central East Madagascar. The altitude of the corridor varies between 200 and 1,500 m, with most of the project area encompassing a mid-range of approximately 700 to 1,000 m and a slope range of 0 to 60 degrees. The corridor has a highly broken relief, with deep, enclosed valleys and summits that can attain 1,500 m. Many of the valley floors are suitable for rice growing but are inaccessible and small in area (few are larger than 10 ha).

Climate conditions

Situated on the eastern slopes of Madagascar, the CAZ corridor is influenced by the 'Alizée (trade winds) year-round. Consequently it experiences sustained rainfall over the year. The

global climate of the region has two wet seasons: the hot and rainy season from September to May; and the cool season with lighter rainfall from June to August. There is no marked dry season in the corridor, but rainfall is lower during the cool season. Tropical storms and cyclones often bring heavy rainfall. Mean annual precipitation in the Andasibe-Mantadia National Park is 1,700 mm. Mean monthly temperatures vary between 14°C (August) and 24°C (January). At the Zahamena National Park the annual rainfall is 1,500 - 2,000 mm, with higher levels for the eastern portion of the reserve as well as for the higher altitudes. During the winter month the temperatures can fall to minimum values of 10 - 15°C.

Hydrology

The project encompasses a vast watershed that is the source of eight large rivers and a multitude of water systems, the largest of which include the Sahatandra, Ivohitra, Rianila, Ivondro, Ivoloina, Onibe, Ihofika, Namarafana, SahaTavy, Managory, Simianona, Marimboha, Manatsatrana, Onibe and Fanandrahana. These rivers are the source of potable water for the regional populations and are critical for agriculture. Four of the major rivers supply the Andekaleka and Volobe hydroelectric stations.

Geology

The geological substrate of the region is crystalline bedrock composed of elements of the Beforona-Alaotra group, characterised by rocks and minerals such as amphibolite, charnockite, amphibole, and a number of basic and ultra-basic rock intrusions. A graphite system is also present. The soil is mainly composed of lateritic clays. Figure 7 below compares the project area in relation to soil types. Peatlands are not common in Madagascar and as shown in the figure, they do not occur in the project area and its vicinity,

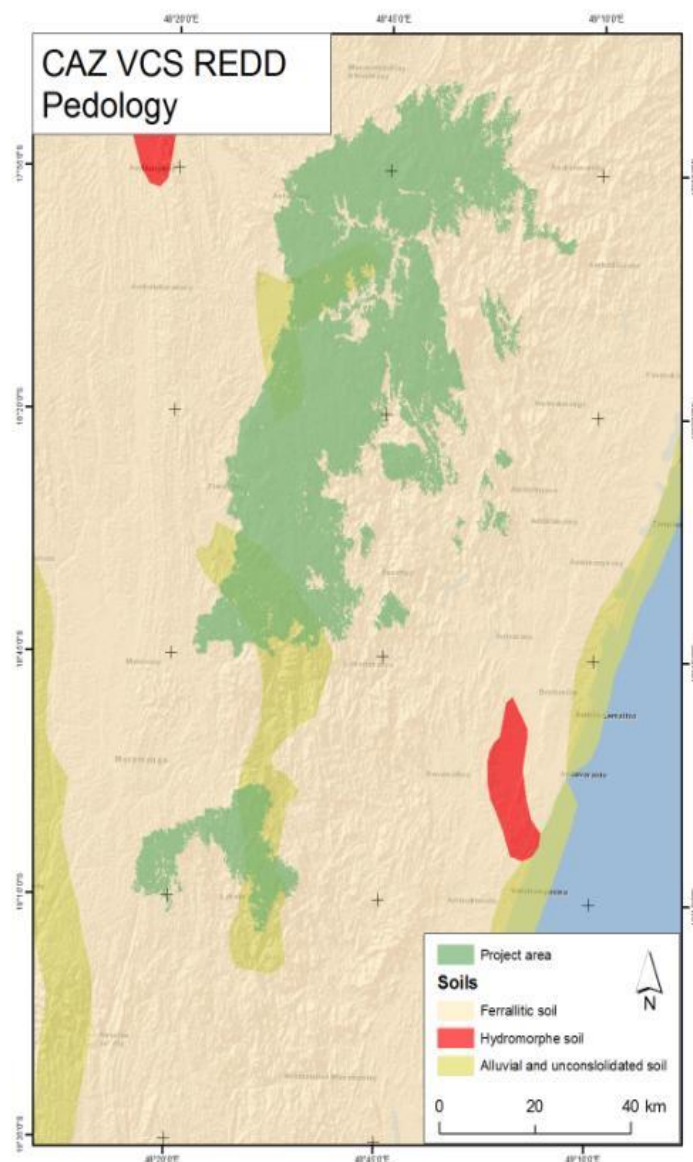


Figure 7. Project location in relation to soil types

Eligibility Criteria

This is not a grouped project.

Leakage Management

The significant cause of unplanned deforestation is slash-and-burn agriculture by local farmers (see section 2.4 Baseline Scenario). Given the nature of the project activities and that the drivers and agents of deforestation are for subsistence farming, no market leakage, or leakage related to investment in the project area and alternative livelihood programmes is foreseen. The only leakage type likely to occur because of the project activity is activity shifting or displacement. Foreseeable leakage is therefore limited to the displacement of slash-and-burn agriculture by local people to meet their needs.

The project has undertaken the following measures to fully mitigate displacement leakage:

Leakage belt: A leakage belt has been defined using a mobility analysis in accordance with the VM00015 methodology Version 1.1.

Leakage management areas: the project has delimited non forested leakage management areas that fully encompass the area of activity of all of the agents of deforestation as well as their places of residence. Within the leakage management areas a concerted and long term programme of activities has been put into place to address the long term livelihood needs of the agents of deforestation and to stabilise land-use. These actions are described in section 1.8 and include:

- Conservation agreements, where local people are directly paid for forest conservation actions;
- Development projects and technical support to provide alternative livelihood options for the community members that have traditionally depended on slash and burn agriculture;

These activities will be funded from 50% of the revenues raised from the sale of VCU.

The leakage management areas are defined as non forest areas within a 2km radius of the project boundary. The activities in this leakage management area are therefore directly targeting the individuals who would potentially cut new land within the forest.

Definition of the project boundary: the boundaries of the protected area, as well as the zoning of the protected area into different management areas, and consequently the areas of forest that are to be conserved, was done with the full participation and agreement of the local stakeholders (see section 1.8). Communities defined the boundaries of the community use areas, the sustainable use forest and the protected forest areas according to their anticipated needs.

Social impact assessment: subsequent to the final delimitation and zoning of the protected area, a detailed social impact assessment was established to identify households that might incur losses due to the management rules of the project. A conservative approach was taken to this assessment in that potential benefits were not considered in the assessment (i.e. net losses were not calculated). This assessment followed the methodology of the World Bank's operational procedures 4.12 except that it was more conservative because only potential losses were considered rather than net losses. During the assessment, mitigation measures for those households that might be negatively affected were defined. These mitigation measures are being put in place to ensure that there is no negative social impact of the project.

Commercially Sensitive Information

No information has been excluded from the public version of the PD.

Further Information

There is no further relevant information that not been included elsewhere in the document.

2 APPLICATION OF METHODOLOGY

2.1 Title and Reference of Methodology

Title: Methodology for Avoided Unplanned Deforestation

Reference: VM0015, Version 1.1, approved by VCS on December 03, 2012.

The sequence and steps as prescribed in the approved methodology were followed to establish the baseline and estimate the ex-ante GHG emission reductions. To conform to the VCS PD template, the methodological steps ("VM step X") are presented under the relevant VCS PD section titles. The "VM Table" numbers of this document match those of the methodology, excluding VM Tables that were not applicable to the project.

2.2 Applicability of Methodology

The project meets the five applicability conditions of the methodology as follows:

- a) The single significant cause of deforestation is unplanned slash-and-burn agriculture by subsistence farmers in lands that are not legally authorised and documented to be converted to non-forest (see sub-step 1b of section 2.5). The principal baseline activity is thus unplanned deforestation for cultivation.

Subsistence harvesting of timber and collection of firewood by rural communities are baseline activities that take place in the reference region. Illegal, small-scale selective logging has historically also taken place throughout the accessible forests included in the reference region. Neither of these activities causes deforestation according to the definition of forest used for this project, nor do they lead to a statistically significant decrease in carbon stocks because the removal of biomass is low by comparison to the natural variation of carbon stocks in undisturbed natural forest. Furthermore, because small-scale, selective logging is illicit, and the subsistence harvesting of timber and firewood are unplanned, these activities cannot be reliably mapped. Forests have reached a steady state in terms of carbon stock since subsistence collection of timber and firewood is at extremely low levels and so does not cause a continued reduction of carbon stocks in the baseline;

Carbon stock measurements have been taken from a wide variety of locations that have experienced the baseline uses and are an accurate representation of this steady state carbon stock. Forest is therefore old-growth natural forest that in the baseline experiences low levels of use from timber harvesting and firewood collection, but which has constant carbon stocks. The single, measurable cause of deforestation and carbon stock loss is *Tavy* slash-and-burn agriculture.

- b) The project activities will avoid the baseline deforestation of old-growth natural forest to conversion to land in a *Tavy* agricultural and fallow system. The project area has two forest management regimes (described in section 1.8): a strict conservation zone, where no extraction of timber products is permitted; and a sustainable-use zone, where controlled collection of fuelwood and timber products is permitted. The project activities are therefore a combination of the eligible categories A and B. How the scope of the

methodology is applicable to the project activities is summarised in VM Table 1 below. Carbon stock increases in the project scenario are conservatively omitted.

VM Table 1. Scope of project activities (highlighted in yellow)

			PROJECT ACTIVITY	
			Protection without logging, fuel wood collection or charcoal production	Protection with controlled logging, fuel wood collection or charcoal production
BASELINE	Deforestation	Old-growth without logging	A	B
		Old-growth with logging	C	D
		Degraded and still degrading	E	F
		Secondary growing	G	H
	No-deforestation	Old-growth without logging	No change	Degradation
		Old-growth with logging	IFM	IFM-RIL
		Degraded and still degrading	IFM	IFM
		Secondary growing	No change	Degradation

- c) The project area is defined using a conservative definition of forest (Harper et al. 2007 and MINENVEFT et al., 2009) and is comprised of old-growth natural forest. This more than meets the DNA definition of forest and is the same one as that used in the government's national analysis of deforestation for 1990-2000-2005.
- d) All land included within the project area qualified as forest at least 10 years prior to the project start date according to the adopted definition of forest. The interpretation of Landsat images from 1990 demonstrates unequivocally that the project area was forest in 1990. Full details of the interpretation of these data and demonstration that the project area was forest on 1990 are presented in section VM Step 2.
- e) The project area does not include forested wetlands growing on peat (see section 1.13), but comprises forest growing on hillsides.

2.3 Project Boundary

VM Step 1: Definition of boundaries

VM 1.1 Spatial boundaries

Vector or raster files that unambiguously define the spatial boundaries of the project are provided with the PD. Figure 1 illustrate the spatial boundaries of the project.

VM 1.1.1 Reference region

Given that to date:

Neither a sub-national nor a national baseline exists that meets VCS or VM0015/Table 2 specific guidance on applicability of existing baselines (see RPP, 2010);

Neither Madagascar nor the sub-national region within which the project area falls has been divided in spatial units for which deforestation baselines will be developed following VCS or UNFCCC rules (see RPP, 2010).

The national government is the project proponent and confirms that there are not any such divisions endorsed by the government for which baselines will be developed.

Therefore the project proponent defines a reference region specific to the project in order to determine the baseline of the project area. The reference region encompasses the project area and the leakage belt and covers an area of 4,966,685 ha, approximately twenty two times larger than the project area. The limiting coordinates are: upper left coordinates 46° 55' 51.495"E and 16° 39' 28.7244"S; lower right coordinates 49° 25' 43.4676"E and 25° 3' 56.1276"S. It encompasses most of the eastern rainforest from Mahavelona (Fenerive Est) to Taolagnaro (Fort-Dauphin).

Overall deforestation patterns observed in the reference region represent a credible proxy for possible future deforestation within the project area as the reference region meets the three main criteria of the approved methodology:

Agents and drivers of deforestation:

- **Agent groups:** The agents of deforestation both within the reference region and the project area are almost entirely subsistence farmers practicing slash-and-burn agriculture (*Tavy*). This is the principal traditional livelihood of rural people living close to forest throughout the eastern rainforest region (e.g. see Aubert *et al.* 2003; Messerli, 2004; Serpantie *et al.* 2007).
- **Infrastructure drivers:** No new transport infrastructure development took place within the reference region during the reference period. Major construction for the Ambatovy mine and associated pipeline to the south of the project area was constructed after the last year of the reference period, 2005 (see the mine's website www.ambatovy.com). Since the mine site constitutes planned deforestation and there is no precedent for such new infrastructure development in the reference period, the baseline projections of deforestation exclude it and therefore will be conservative. No other new or improved infrastructure is expected to develop near or inside the project area.
- **Other spatial drivers expected to influence the project area:** The reference region does not include any other spatial drivers that are expected to influence the project area during the baseline period.

Landscape configuration and ecological conditions:

- **Forest/vegetation classes:** Both the reference region and the project area fall within the Madagascar eastern humid rainforest biome and are comprised of the same forest class (Moat and Smith, 2007; MEF, 2010). The boundaries of the reference region were chosen to exclude forest types not found at the project site.
- **Elevation:** The altitude of the project area ranges from 195 to 1,543 m while that of the reference region ranges from 0 to 2,021 m. The altitude range in the project area is comprised within the range of altitude in the reference region. At least 90% of the project area is within 90% of the elevation range of the rest of the reference region.
- **Slope:** The slope within the project area ranges from 0 to 75 degrees with an average of 15.7 degrees, while the slope within the reference region ranges from 0 to 81 degrees with an average of 15.2 ±1.52 (the 10% upper and lower bounds). The

average slope in the project area (15.7 degree) is therefore within the range of the average slope in the reference region plus or minus 10% (13.3 to 16.3 degrees).

- **Rainfall:** The mean annual rainfall in the project area ranges from 1,197 mm to 2,701 mm/year, with an average for the entire project area of 1,685 mm/year. The mean annual rainfall in the reference region is 1,804 mm/year. The average annual rainfall of the project area is therefore within $\pm 10\%$ of that of the reference region (1,623 to 1,984 mm/year).

At least three of the four VM0015 conditions related to landscape configuration and ecological conditions are therefore satisfied.

Socio-economic and cultural conditions:

- **Legal status of the land:** The land within the project area is state-owned and subject to slash and burn agriculture by subsistence farmers. The same legal status and tenure of land that are found within the project area are prevalent in the forests throughout the reference region. Established protected areas are not included in the reference region.
- **Land tenure:** The land tenure of subsistence farmers is largely governed by traditional and customary rights. A limited number of land owners, who have the means, will formalise their land tenure with the cadastral services and hold legal title to the land. The land-tenure system in the project area in the baseline case is found throughout the reference region.
- **Land use:** In both the project area and the reference area, forest is converted to temporary cropland that then enters into a slash and burn cycle of use for agriculture followed by a fallow period before re-burning occurs. The current and projected classes of land-use in the project area are therefore found throughout the reference region.
- **Enforced policies and regulations:** The same policies, legislation and regulations, as well as the same level of enforcement, apply to both the project area and the reference region. Forest areas are state land in which deforestation is illegal but this is poorly enforced. The use of forest resources is prohibited without a licence or community management contract (GCF). GCF contracts are generally difficult for communities to get without financial and technical support from a donor project. Local people do use forest resources without authorisation but at the risk of prosecution. Similarly they do clear new areas of land for slash and burn because enforcement is extremely weak. The existing, established protected areas are excluded from the reference region as these have better enforcement in place and have been demonstrated to have effectively reduced deforestation.

The deforestation patterns in the entire reference region are representative of those within the project area. The reference region includes areas where substantial deforestation had occurred during the reference period, therefore making it suitable for calibrating and validating the spatial model of deforestation patterns. Making the reference region any larger would include different relationships between drivers and deforestation since it would include areas of different forest type where agents of deforestation and socio-economic conditions are different.

VM 1.1.2 Project area;

The location of the project area, including the administrative regions in which it falls, is presented in detail in section 1.9, Project Location.

The project area includes all forest areas within the boundaries of the Ankeniheny-Zahamena Corridor Protected Area as well as the community managed areas bordering the protected area. The GIS files of the physical boundaries that define the land included in the project area are available to the validator on request. As is described in section 1.8 Description of the Project Activity, the protected area is divided into different management zones. Table 6.6 and Figure present which protected area management zones make up the project area and the leakage management areas respectively. The project area is constituted by:

- forest within the strict conservation zone (Category A);
- sustainable use forest areas within the sustainable use zone; these forest areas are principally community-managed (Category B);
- and the sustainable use forest areas within the community managed areas bordering the CAZ protected area (Category B).

Table 6. Protected area management zones and the corresponding VCS spatial boundaries

Zone	Corresponding VCS spatial boundary
Protected Area	
1. Strict conservation zone	
Strict conservation zone	Project area (Cat. A)
2. Buffer zone	
Sustainable use forest	Project area (Cat. B)
Settlement enclave	Leakage management areas
Community Managed Forest areas contiguous with the Protected Area	Project area (Cat. B)
Non-forest land within 2km of project boundary	Leakage management areas

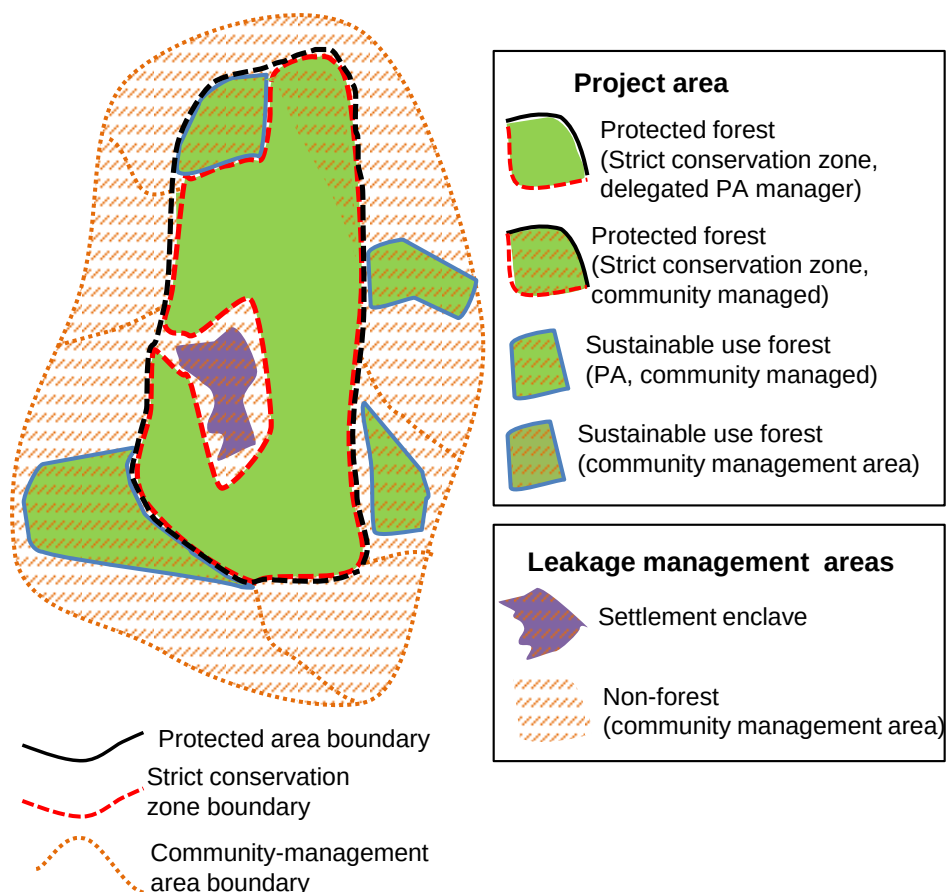


Figure 8. Simplified representation of the division of the protected area into the project area and leakage management areas

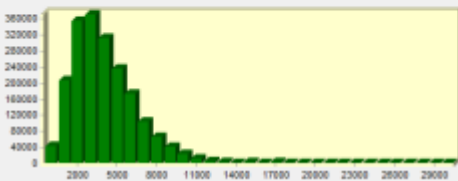
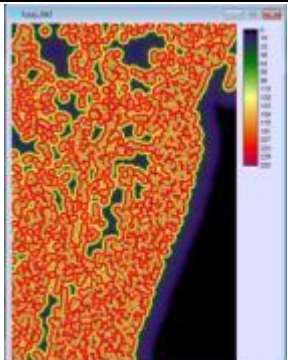
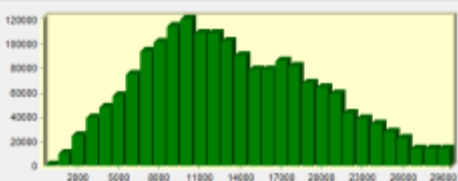
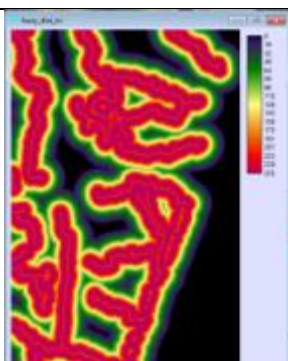
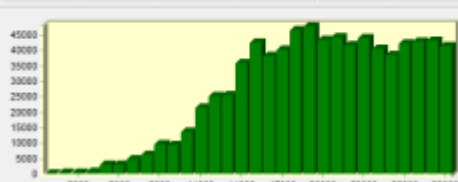
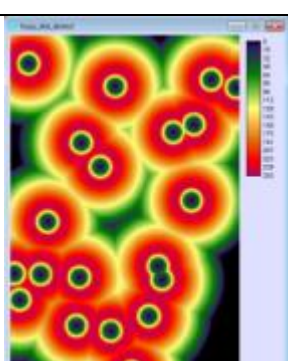
A description of current land-tenure and use rights of the project area is detailed in section 1.12.1 Rights of Use, while the project proponent and other participants involved in the project are presented in sections 1.3 and 1.4 respectively.

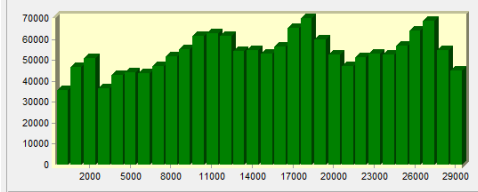
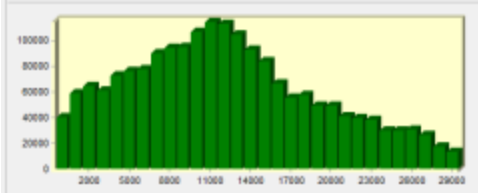
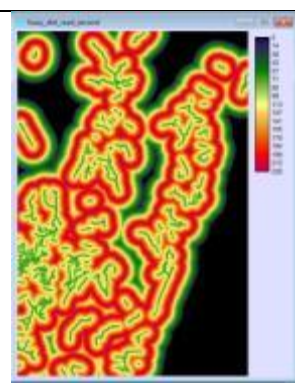
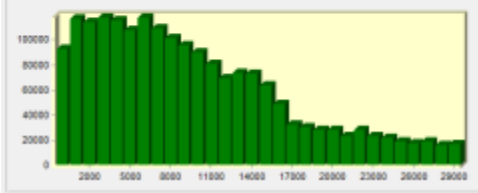
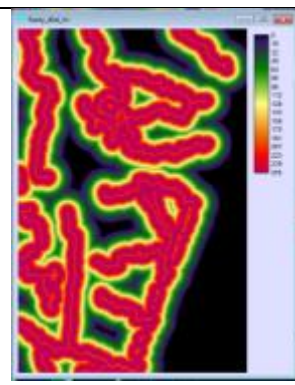
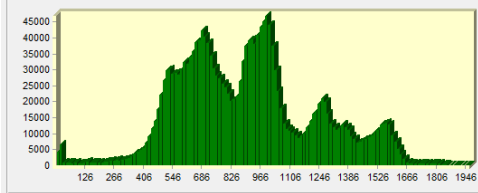
VM 1.1.3 Leakage belt

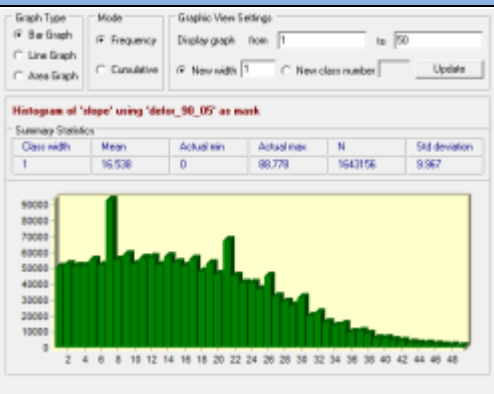
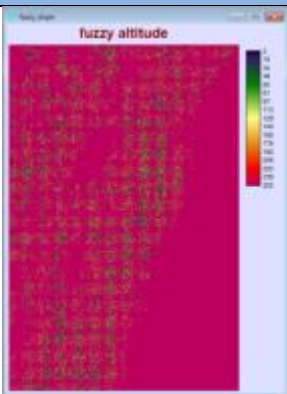
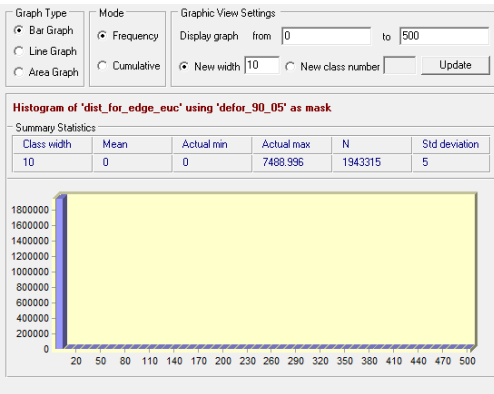
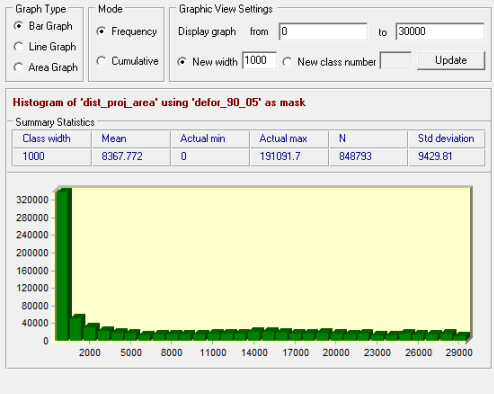
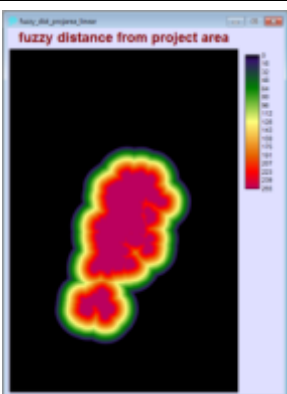
Since the single cause of significant deforestation throughout the reference region is slash-and-burn agriculture by subsistence farmers, a mobility analysis (Option II) was used to define the boundary of the leakage belt. The mobility analysis was done using a Multi-Criteria Evaluation (MCE), a module of IDRISI. Based on local knowledge of the likelihood of the local population moving and the factors that drive deforestation, several criteria were chosen to evaluate the mobility of the population, including:

- Distance to fokontany (point)
- Distance to communes (point)
- Distance to district (point)
- Distance to primary road
- Distance to secondary road
- Distance to river
- Altitude
- Slope
- Distance from forest edges
- Distance from project area

The first step on the MCE was to generate the fuzzy maps for each variable. We applied the fuzzy function (the values ranged from 0 to 255, where 0 is the most suitable and 255 is the least suitable) on factor maps of each of the criteria a) – j) listed above.

Variables	Relationship with deforestation 1990-2005	Fuzzy membership variable result																																							
Distance to fokontany	Graph Type: ☒ Bar Graph ☐ Line Graph ☐ Area Graph Mode: ☒ Frequency ☐ Cumulative Graphic View Settings: Display graph: from 0 to 30000 ☒ New width 1000 ☐ New class number Update Histogram of 'dist_fkt_esc' using 'defor_90_05' as mask Summary Statistics <table><thead><tr><th>Class width</th><th>Mean</th><th>Actual min</th><th>Actual max</th><th>N</th><th>Std deviation</th></tr></thead><tbody><tr><td>1000</td><td>4414.095</td><td>0</td><td>122916.4</td><td>1943015</td><td>2563.187</td></tr></tbody></table> 	Class width	Mean	Actual min	Actual max	N	Std deviation	1000	4414.095	0	122916.4	1943015	2563.187	Distance to commune	Graph Type: ☒ Bar Graph ☐ Line Graph ☐ Area Graph Mode: ☒ Frequency ☐ Cumulative Graphic View Settings: Display graph: from 0 to 30000 ☒ New width 1000 ☐ New class number Update Histogram of 'dist_commune_esc' using 'defor_90_05' as mask Summary Statistics <table><thead><tr><th>Class width</th><th>Mean</th><th>Actual min</th><th>Actual max</th><th>N</th><th>Std deviation</th></tr></thead><tbody><tr><td>1000</td><td>12791.8</td><td>0</td><td>124279.7</td><td>1822637</td><td>6254.185</td></tr></tbody></table> 	Class width	Mean	Actual min	Actual max	N	Std deviation	1000	12791.8	0	124279.7	1822637	6254.185	Distance to district	Graph Type: ☒ Bar Graph ☐ Line Graph ☐ Area Graph Mode: ☒ Frequency ☐ Cumulative Graphic View Settings: Display graph: from 0 to 30000 ☒ New width 1000 ☐ New class number Update Histogram of 'dist_dist_esc' using 'defor_90_05' as mask Summary Statistics <table><thead><tr><th>Class width</th><th>Mean</th><th>Actual min</th><th>Actual max</th><th>N</th><th>Std deviation</th></tr></thead><tbody><tr><td>1000</td><td>20320.95</td><td>0</td><td>122266.2</td><td>792421</td><td>5081.478</td></tr></tbody></table> 	Class width	Mean	Actual min	Actual max	N	Std deviation	1000	20320.95	0	122266.2	792421	5081.478
Class width	Mean	Actual min	Actual max	N	Std deviation																																				
1000	4414.095	0	122916.4	1943015	2563.187																																				
Class width	Mean	Actual min	Actual max	N	Std deviation																																				
1000	12791.8	0	124279.7	1822637	6254.185																																				
Class width	Mean	Actual min	Actual max	N	Std deviation																																				
1000	20320.95	0	122266.2	792421	5081.478																																				

Variables	Relationship with deforestation 1990-2005	Fuzzy membership variable result												
Distance to primary road: No relationship found based on the histogram, variable not used	Graph Type ☒ Bar Graph ☐ Line Graph ☐ Area Graph Mode ☒ Frequency ☐ Cumulative Graphic View Settings Display graph from 0 to 30000 ☒ New width 1000 ☐ New class number Update Histogram of 'dist_road_main_euc' using 'defor_90_05' as mask Summary Statistics <table><tr><th>Class width</th><th>Mean</th><th>Actual min</th><th>Actual max</th><th>N</th><th>Std deviation</th></tr><tr><td>1000</td><td>15701.32</td><td>0</td><td>121163.9</td><td>1602591</td><td>8408.756</td></tr></table> 	Class width	Mean	Actual min	Actual max	N	Std deviation	1000	15701.32	0	121163.9	1602591	8408.756	n/a
Class width	Mean	Actual min	Actual max	N	Std deviation									
1000	15701.32	0	121163.9	1602591	8408.756									
Distance to secondary road	Graph Type ☒ Bar Graph ☐ Line Graph ☐ Area Graph Mode ☒ Frequency ☐ Cumulative Graphic View Settings Display graph from 0 to 30000 ☒ New width 1000 ☐ New class number Update Histogram of 'dist_road_secen_euc' using 'defor_90_05' as mask Summary Statistics <table><tr><th>Class width</th><th>Mean</th><th>Actual min</th><th>Actual max</th><th>N</th><th>Std deviation</th></tr><tr><td>1000</td><td>12548.52</td><td>0</td><td>122804.7</td><td>1084225</td><td>7080.498</td></tr></table> 	Class width	Mean	Actual min	Actual max	N	Std deviation	1000	12548.52	0	122804.7	1084225	7080.498	
Class width	Mean	Actual min	Actual max	N	Std deviation									
1000	12548.52	0	122804.7	1084225	7080.498									
Distance to river	Graph Type ☒ Bar Graph ☐ Line Graph ☐ Area Graph Mode ☒ Frequency ☐ Cumulative Graphic View Settings Display graph from 0 to 30000 ☒ New width 1000 ☐ New class number Update Histogram of 'dist_river_euc' using 'defor_90_05' as mask Summary Statistics <table><tr><th>Class width</th><th>Mean</th><th>Actual min</th><th>Actual max</th><th>N</th><th>Std deviation</th></tr><tr><td>1000</td><td>9029.59</td><td>0</td><td>122606.4</td><td>1081253</td><td>7183.648</td></tr></table> 	Class width	Mean	Actual min	Actual max	N	Std deviation	1000	9029.59	0	122606.4	1081253	7183.648	
Class width	Mean	Actual min	Actual max	N	Std deviation									
1000	9029.59	0	122606.4	1081253	7183.648									
Altitude: No relationship found based on expert knowledge, variable not used	Graph Type ☒ Bar Graph ☐ Line Graph ☐ Area Graph Mode ☒ Frequency ☐ Cumulative Graphic View Settings Display graph from 0 to 1968 ☒ New width 14 ☐ New class number Update Histogram of 'altitude_rci' using 'defor_90_05' as mask Summary Statistics <table><tr><th>Class width</th><th>Mean</th><th>Actual min</th><th>Actual max</th><th>N</th><th>Std deviation</th></tr><tr><td>14</td><td>902.235</td><td>0</td><td>1968</td><td>1943315</td><td>322.263</td></tr></table> 	Class width	Mean	Actual min	Actual max	N	Std deviation	14	902.235	0	1968	1943315	322.263	n/a
Class width	Mean	Actual min	Actual max	N	Std deviation									
14	902.235	0	1968	1943315	322.263									

Variables	Relationship with deforestation 1990-2005	Fuzzy membership variable result
Slope		
Distance from forest edges: No relationship found based on the histogram; variable not used		n/a
Distance from project area		

The next step was to determine the relative weights for the factors maps. The weights were developed by providing a series of pairwise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The resulting weights were used as input for the MCE module using a weighted linear combination.

The eigenvector of weights are as follows :

- Fuzzy distance to commune : 0.2547
- Fuzzy distance to district : 0.0893
- Fuzzy distance to fokontany: 0.3861
- Fuzzy distance to project area: 0.1768
- Fuzzy distance to river : 0.0415

- Fuzzy distance to secondary road : 0.0237
- Fuzzy slope : 0.0279

The consistency ratio ranges from 0 to 1 and the closer that it is to 0 the better. The consistency ratio of the MCE was of 0.09 and was judged as acceptable.

Finally in the MCE, we excluded (used as constraint) the areas inside the project area boundaries, protected areas and all non-forest areas (since we are interested only in the agent moving into forest areas).

The output is a map of the potential of access to forest, with values ranging from 0 to 255, where 0 is inaccessible and 255 equates with the highest probability of being accessed or for the population to move into (see Figure). The leakage belt has been defined as the forest areas falling within this probability map and containing enough forest to absorb more than 100% potential displacement of baseline deforestation due to the project implementation. The resulting leakage belt is shown in Figure 0. The leakage belt defined here includes the upper 1/2 bound of this probability map equaling an area of 89,155 hectares of forest and would therefore be large enough to absorb more than the entire 71,673 hectares of projected deforestation in the project area and leakage belt during the baseline period if we assume 100% leakage.

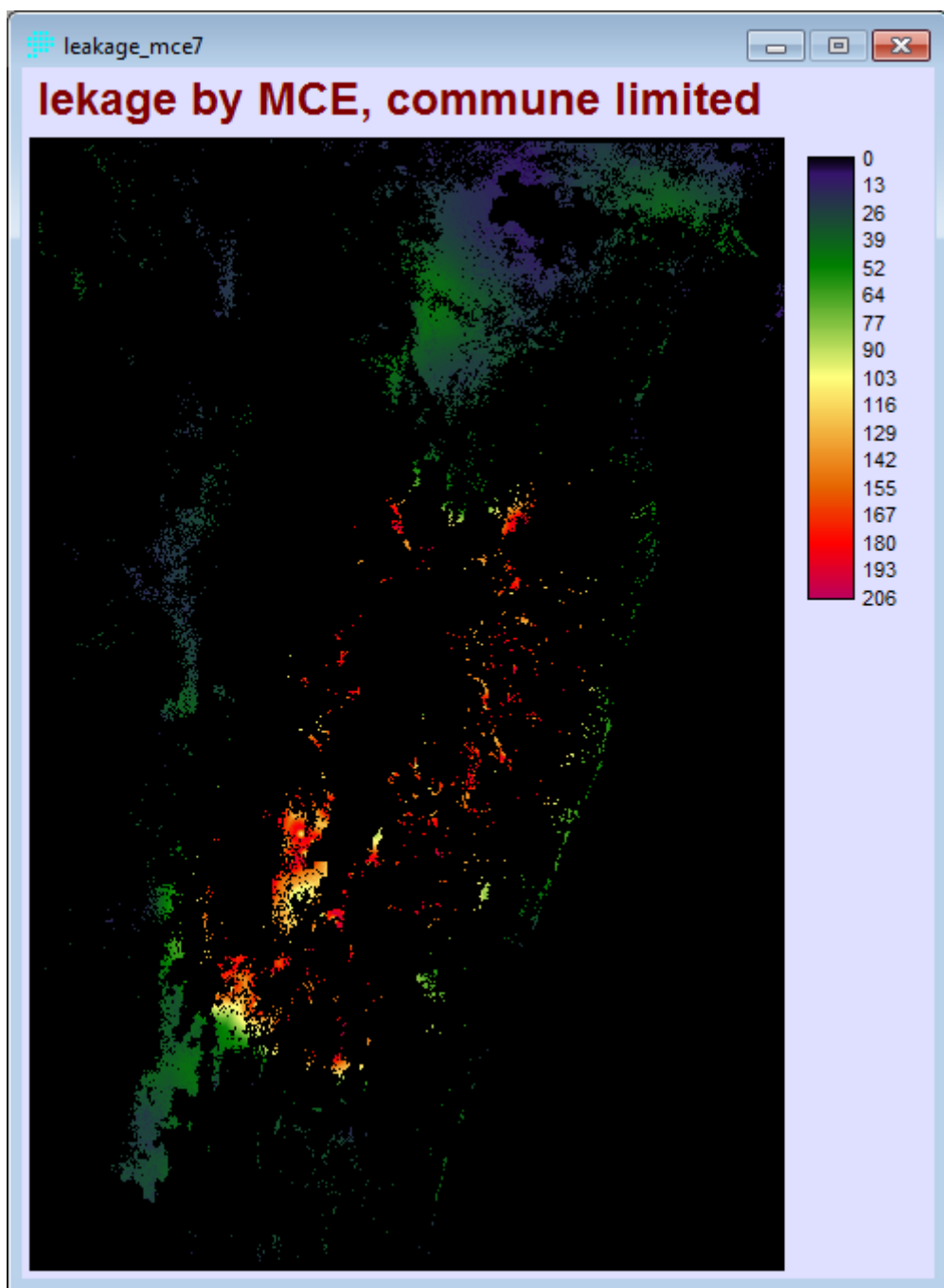


Figure 9. Map of accessibility potential to forest areas external to the project area



Figure 10. CAZ leakage belt. The red areas fall within are the upper half boundary of the accessibility potential map and constitute the leakage belt

VM 1.1.4 Leakage management areas

The leakage management areas include all non-forest land within the community-managed areas (both within the protected area as well as within the fokontany bordering the protected area). The boundaries of the leakage management areas are defined by:

- the limits of the settlement enclave zones within the protected area;
- a 2km zone around the limit of the project area or forest contiguous with the project area.

Summary of the VCS spatial boundaries of the project

GIS files of the boundaries of the spatial domains of the project are available with this PD and are illustrated in Figure 1. Table 7 summarises the total area of each of these. Parcel IDs and coordinates of centroids are listed in Annex 3.

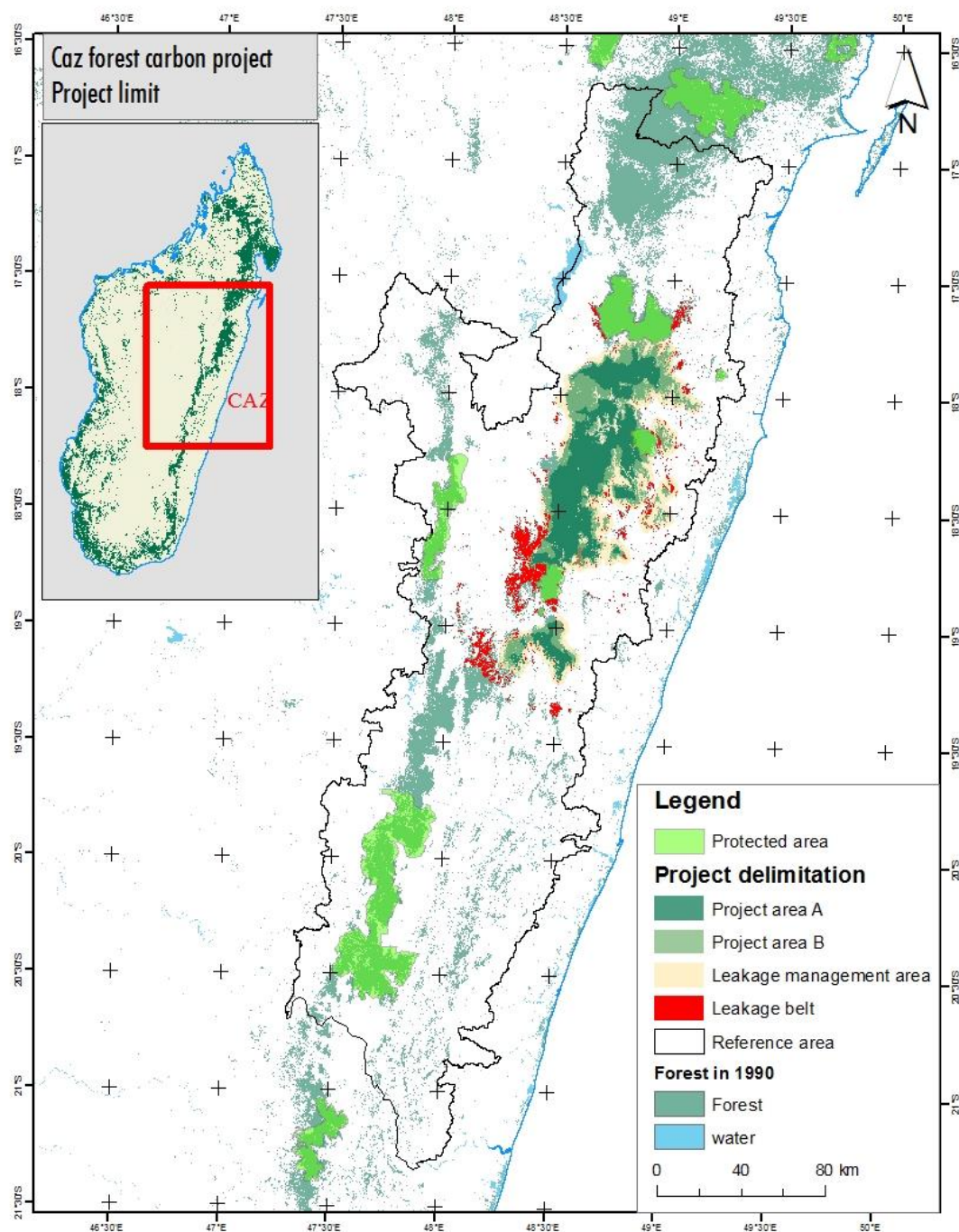


Figure 11a. Spatial boundaries of the Ankeniheny Zahamena Corridor REDD Project

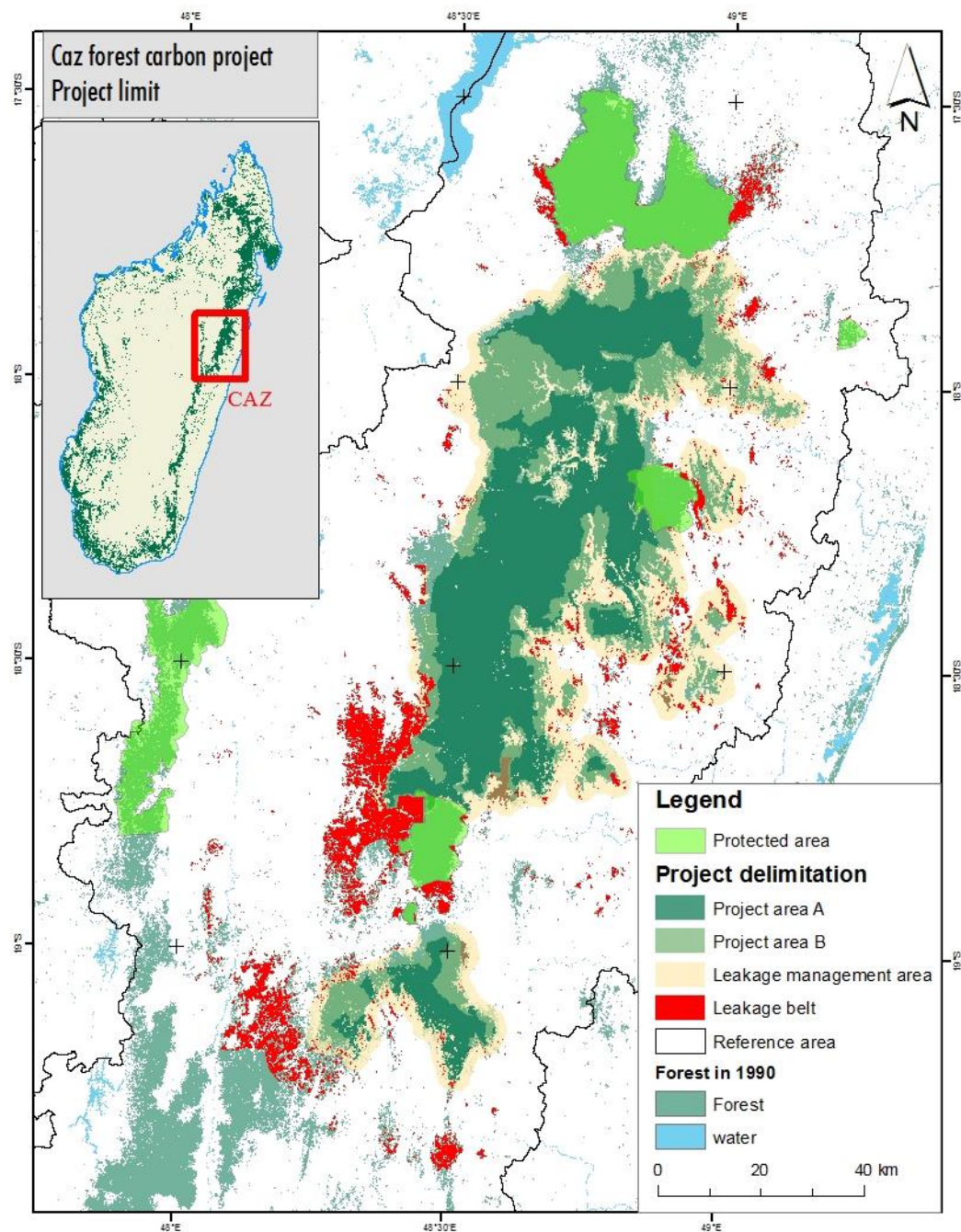


Figure 11b. Spatial boundaries of the Ankeniheny Zahamena Corridor REDD Project

Table 7. Summary of the VCS spatial boundaries of the CAZ RED project

VCS Spatial boundary	Area (ha)
Reference region (forest and non-forest)	4,966,685
Project area	370,032
Project area (Category A)	234,165
Project area (Category B)	135,868
Leakage belt (forest)	89,155
Leakage management areas (non-forest)	178,428

VM 1.1.5 Forest.

This project aims to reduce GHG emissions from unplanned deforestation. For this project, we use a definition of forest that falls within, and is more conservative than, the national definition of forest as submitted to the UNFCCC⁴. “Forest” includes those areas with: a) tree-crown cover of over 30 percent, b) a canopy height of over 5m, c) has a minimum patch size of 2 hectares, and d) is not part of an agricultural use or in only a temporary state that may meet the above structural criteria. Criteria (a) and (b) follow the national definition. While these two parameters are not precisely measurable with satellite data, our past national-level mapping studies, which have involved the use of high-resolution aerial photography, ancillary data and expert workshops, indicate that our methodology does not result in the inclusion of very open-canopy formations or low-height woody vegetation in our forest class in this region (MINENVEFT et al., 2009, Harper et al., 2007). Criteria (c) differ from the national definition, which uses 1 hectare. However, all evidence from satellite data and field knowledge indicates that the total proportion and area of forest that is in isolated patches of between 1 to 2 hectares are insignificant, i.e. likely less than one percent of total forest area. The last criteria (d) is to exclude bush fallow and young secondary formations from mature forest, as these are in a temporary state associated with *Tavy*. Inclusion of these formations with mature forest would result in a major confusion of the deforestation rates, since all fallow-cycles would be included therein. These secondary formations are readily distinguishable in the Landsat images we use, as evidenced by the validation studies of the previous national maps as well as ample literature on remote sensing of tropical forests. Selectively-logged forests remain in our forest category, as they are forests that continue to have mostly closed canopies and are distinguishable from non-forest vegetation with the satellite imagery. Thus we report on deforestation as the clear-cutting of mature, natural forest, and this does not include selective logging or fallow clearing.

⁴ <http://cdm.unfccc.int/DNA/index.html>

VM 1.2 Temporal boundaries

VM 1.2.1 Starting date and end date of the historical reference period

The historical reference period is from 1990 to 2005, totalling 15 years.

VM 1.2.2 Starting date of the project crediting period of the AUD project activity

Following the end of project preparation activities in 2005-2007, various activities to reduce deforestation were started at the end of 2007. A key milestone for the project was the completion of the public consultation process with the local communities in December 2007. The project start date is therefore taken as December 30, 2007 to ensure that the first calendar year of the project is 2008. This date represents the start date of the first project crediting period of the AUD activity; the end date is December 29, 2037.

VM 1.2.3 Starting date and end date of the first fixed baseline

The start date of the first fixed baseline is December 30, 2007, and the end date is December 29, 2017.

VM 1.2.4 Monitoring period

The minimum duration of a monitoring period will be one year and the maximum duration will be one fixed baseline period.

VM 1.3 Carbon pools

Of the six carbon pools eligible in this methodology, the project seeks credit for three: above-ground live tree biomass, below-ground biomass and dead wood (see VM Table 3 below).

VM Table 3. Carbon pools included or excluded within the boundary of the proposed REDD project activity

Carbon pools	Included / TBD ¹ / Excluded	Justification / Explanation of choice
Above-ground	Tree: Included	Carbon stock change in this pool is always significant
	Non-tree: Excluded	Final land cover in the baseline does not include perennial crops.
Below-ground	Included	The change in this carbon pool is expected to be significant
Dead Wood	Included	The change in this carbon pool is expected to be significant
Harvested wood products	Excluded	The level of logging in the baseline is very low intensity to make this pool significant. In addition, the project will not significantly reduce this pool in comparison to the baseline. Excluding HWP is always conservative in the project scenario.
Litter	Excluded	Excluded according to VCS AFOLU guidelines (v3.2).

Carbon pools	Included / TBD ¹ / Excluded	Justification / Explanation of choice
Soil organic carbon	Excluded	The baseline land-use of the project area is the conversion of forest to cropland by slash-and-burn, followed by repeated cycles of burning. The change in this carbon pool is expected to be significant. By not including it, we are conservatively underestimating emissions caused by deforestation.

VM 1.4 Sources of GHG emissions

Since the dominant method of conversion is slash-and-burn, the project also seeks to reduce the associated non-CO₂ emissions from biomass burning, specifically CH₄. The project does not seek any reductions in emissions from forest damage from fire, pest or disease, nor emissions from agricultural land management, such as reduction in fertilizers or changes in tilling. The project also does not seek emissions reductions in the combustion of fossil fuels or livestock emissions (see VM Table 4). Raising livestock is not a widespread activity in the baseline, nor will the RED project activity promote livestock-raising or lead to an increase in it. Thus, emissions from this source are not expected to increase in the project relative to the baseline scenario.

VM Table 4. Sources and GHG included or excluded within the boundary of the proposed RED project activity

Sources	Gas	Included/TBD ¹ / excluded	Justification / Explanation of choice
Biomass burning	CO ₂	Excluded	Counted as <i>carbon stock</i> change
	CH ₄	Included	A significant source as fire would have been used to clear the land in the baseline scenario.
	N ₂ O	Excluded	Considered insignificant
Livestock emissions	CO ₂	Excluded	Not a significant source
	CH ₄	Excluded	Not a significant source
	N ₂ O	Excluded	Not a significant source

2.4 Baseline Scenario

VM Step 2: Analysis of historical land-use and land-cover change

VM 2.1 Collection of appropriate data sources;

Land cover change data exist for 1990, 2000 and 2005, via analysis of mid-resolution satellite imagery the entire reference area (Harper, et al 2007, Jarijala 2009). This analysis of deforestation rates and patterns has been produced using the source satellite data listed in VM Table 5, and includes three dates over the 15-year historical reference period: 1990, 2000 and 2005. Ground trothing or validation consisted of comparing results from high resolution images (further details see Harper et al. 2007, Jarijala 2009, and the Supplementary

Information - Land cover land change for CAZ). VM0015 requires that medium resolution spatial data should be used in the land cover and change detection analysis, covering the past 10-15 years from the project start date.. We used Landsat images (30m resolution) for the analysis as this is the most common and freely accessible image. There is however a permanent problem using optical imagery in tropical countries: the common presence of clouds that mask out the landscape from the satellite sensor. Images were selected as close to the target years of 1990, 2000 and 2005 for which near cloud free images were available.

VM Table 5. Data used for historical LU/LC change analysis

Vector (satellite or airplane)	Sensor	Resolution		Coverage	Acquisition date	Scene or point identifier	
		Spatial	Spectral			Path/ latitude	Row/ Longitude
Satellite	TM	30m	6 bands	185x185 km	24-jul-1991	158	77
Satellite	ETM+	30m	8 bands	185x185km	1-nov-1999	158	77
Satellite	TM	30m	6 bands	185x185km	25-apr-2005	158	77
Satellite	TM	30m	6 bands	185x185 km	20-sep-1989	158	76
Satellite	ETM+	30m	8 bands	185x185km	11-nov-1999	158	76
Satellite	TM	30m	6 bands	185x185km	03-aug-2005	158	76
Satellite	TM	30m	6 bands	185x185 km	20-sep-1989	158	75
Satellite	ETM+	30m	8 bands	185x185km	11-nov-1999	158	75
Satellite	TM	30m	6 bands	185x185km	03-aug-2005	158	75
Satellite	TM	30m	6 bands	185x185 km	20-sep-1989	158	74
Satellite	ETM+	30m	8 bands	185x185km	19-apr-2000	158	74
Satellite	TM	30m	6 bands	185x185km	25-apr-2005	158	74
Satellite	TM	30m	6 bands	185x185 km	25-oct-1990	158	73
Satellite	ETM+	30m	8 bands	185x185km	19-apr-2000	158	73
Satellite	TM	30m	6 bands	185x185km	24-mar-2005	158	73
Satellite	TM	30m	6 bands	185x185 km	08-apr-1993	158	72
Satellite	ETM+	30m	8 bands	185x185km	19-apr-2000	158	72
Satellite	TM	30m	6 bands	185x185km	25-mar-2005	158	72
Satellite	TM	30m	6 bands	185x185 km	25-may-1990	159	72
Satellite	ETM+	30m	8 bands	185x185km	12-may-2000	159	72
Satellite	TM	30m	6 bands	185x185km	09-oct-2005	159	72
Satellite	TM	30m	6 bands	185x185 km	10-jul-1990	159	73
Satellite	ETM+	30m	8 bands	185x185km	12-may-2000	159	73
Satellite	TM	30m	6 bands	185x185km	31-may-2005	159	73
Satellite	TM	30m	6 bands	185x185 km	28-apr-1992	159	74
Satellite	ETM+	30m	8 bands	185x185km	17-oct-1999	159	74
Satellite	TM	30m	6 bands	185x185km	10-jan-2005	159	74
Satellite	TM	30m	6 bands	185x185 km	07-apr-1990	159	75
Satellite	ETM+	30m	8 bands	185x185km	17-oct-1999	159	75
Satellite	TM	30m	6 bands	185x185km	09-dec-2004	159	75
Satellite	TM	30m	6 bands	185x185 km	15-apr-1993	159	76
Satellite	ETM+	30m	8 bands	185x185km	17-oct-1999	159	76
Satellite	TM	30m	6 bands	185x185km	10-jan-2005	159	76
Airplane	Aerial survey			transects	2003	Flight plan	Flight plan
Satellite	Quickbird /Digital Globe	2.5m	3 bands		2003-2007		

VM 2.2 Definition of classes of land-use and land-cover;

One forest type was identified in the reference region and further divided into three forest management classes, and one non-forest (post-deforestation use) class was defined for the baseline scenario (VM Table 6):

- **Forest Land:** The reference region is made up of one broad forest type consisting of natural forest greater than fifteen years old and excluding plantation forest. The Forest Land LULC of the reference region is not sub-divided into further strata for the following reasons:
 1. Carbon stock measurements across a range of elevations, forest types and probable levels of exploitation using indirect criteria (based on the vulnerability to deforestation modelled using access and biophysical drivers) show that no further forest strata with statistically distinguishable average carbon densities can be defined in the project area (supportive information has been provided to the validators).
 2. Remote sensing analysis using available imagery for the reference period could not reliably distinguish between different forest types.
 3. Forest Land is comprised of public forest lands. The government of Madagascar and its agencies responsible for the management of this public forest estate have never previously had the means to manage it effectively. Rural communities have previously used resources from the forest area on an informal basis and so accessible areas have potentially been subject to a low level of local use. The definition of strata according to official or supposed management categories in the past would be meaningless.
 4. Subsistence harvesting of timber and collection of firewood by rural communities are baseline activities that take place in the reference region. Illegal, small-scale selective logging has historically also taken place throughout the accessible forests included in the reference region. Neither of these activities causes deforestation according to the definition of forest and deforestation used for this project (see VM 1.1.5), nor do they lead to a significant decrease in carbon stocks above the natural variation seen in undisturbed natural forest (see Supplementary Information - Impact of legal and illegal harvesting on forest degradation in the CAZ REDD project area). Furthermore, because small-scale, selective logging is illicit, and the subsistence harvesting of timber and firewood are unplanned, the boundaries of these activities cannot be reliably mapped. The carbon stocks of the Forest Land have reached a steady state and their future trend is “constant”.
- **Forest Land (Cat. A) and Forest Land (Cat. B):** The project area (in the project scenario) has two forest management regimes (described in section 1.8): a strict conservation zone, where no extraction of timber products is permitted; and a sustainable-use zone, where controlled, subsistence collection of fuelwood and timber products is permitted. Two forest LULCs are therefore defined according to these management categories even though their carbon stocks are not significantly different. The subsistence use of timber and fuelwood from the sustainable use forests will not exceed that which would take place in the baseline and the trend in carbon stocks for Forest Land (Cat. B) is “constant”. Carbon stocks within Forest Land (Cat. A) – the strict conservation zone - are also treated as “constant”.
- **Non-forest land:** The non-forest class to which forest will be converted is a dynamic landscape in a *Tavy* cycle. At any one time, this landscape includes areas under hill rice

or other crop production and recovering fallows of varying ages. As the *Tavy* cycle continues, the spatial arrangement of land under different stages of this cyclical use changes, yet the overall average biomass across the non-forested landscape remains relatively constant. Slight declines are possible via losses in organic matter during successive burnings and potential shortening of fallow cycles. These trends in stocks are believed to be insignificant compared to the emissions from deforestation and their potential reductions.

VM Table 6. List of all land-use and land-cover classes existing at the project start date within the reference region

Class Identifier <i>ID_{cl}</i>	Name	Trend in Carbon stock ¹	Presence in ²	Baseline activity ³			Description (including criteria for unambiguous boundary definition)
				LG	FW	CP	
1	Forest Land	constant	RR, LK	yes	yes	no	Natural forest >15y old, excluding plantations
2	Forest Land (Cat. A)	constant	PA	no	no	no	Natural forest >15y old, excluding plantations; forest occurring within the strict conservation zone of the PA
3	Forest Land (Cat. B)	constant	PA	yes	yes	no	Natural forest >15y old, excluding plantations; forest occurring within the PA and community areas that is for sustainable use
4	Non-forest Land	decreasing	RR, LM	no	no	no	Agriculture mosaic, which includes <i>Tavy</i> crops and fallows

Notes:

1. Note if “decreasing”, “constant”, “increasing”

2. RR = Reference Region, LK = Leakage Belt, LM = Leakage Management Areas, PA = Project Area

3. LG = Logging, FW = Fuel-wood collection, CP = Charcoal Production (yes/no)

4. Each class shall have a unique identifier (ID_{cl}). The methodology sometimes uses the notation icl (= 1, 2, 3, ... icl) to indicate “initial” (pre-deforestation) classes, which are all forest classes; and fcl (= 1, 2, 3, ... fcl) to indicate final” (post-deforestation) classes. In this table all classes (“initial” and “final”) shall be listed.

No areas of land are expected to undergo significant decrease in carbon stocks that would lead to an overestimation of the GHG emission reductions achieved by the project activity since:

- the project uses a conservative definition of forest;
- the trend in carbon stocks for the forest LULCs will be constant or increasing, while that for the Non-forest Land will be decreasing;
- the carbon stocks of the Non-forest Land are conservatively estimated from the *Tavy* cycle areas.

In addition, the project does not seek credits for any increases in carbon stocks in Forest Land (Cat. A) over the baseline. Therefore a single Land-Use and Land-Cover Map representing the spatial distribution of forest classes at the project start date is generated.

VM 2.3 Definition of categories of land-use and land-cover change;

The project defined four land-use and land-cover classes, and three possible combinations of land-use and land-cover change categories, as showed in VM Table 7.a and 7.b.

VM Table 7a. Potential land-use and land-cover change matrix

<i>ID_{ct}</i>		Initial LU/LC class			
		Forest Land	Forest Land (Cat. A)	Forest Land (Cat. B)	Non-forest Land
Final LU/LC class	Forest Land	I1/F1	-	-	-
	Forest Land (Cat. A)	-	I2/F2	-	-
	Forest Land (Cat. B)	-	-	I3/F3	-
	Non-forest Land	I1/F4	I2/F4	I3/F4	I4/F4

VM Table 7b List of land-use and land-cover change categories

<i>ID_{ct}</i>	Name	Trend in Carbon stock	Presence in	Activity in the baseline case			Name	Trend in Carbon stock	Presence in	Activity in the project case		
				LG	FW	CP				LG	FW	CP
I1/F1	Forest Land	constant	RR, LK	yes	yes	no	Forest Land	constant	RR, LK	yes	yes	no
I2/F2	Forest Land (Cat. A)	constant	PA	no	no	no	Forest Land (Cat. A)	constant	PA	no	no	no
I3/F3	Forest Land (Cat. B)	constant	PA	yes	yes	no	Forest Land (Cat. B)	constant	PA	yes	yes	no
I1/F4	Forest Land	constant	RR, LK	yes	yes	no	Non-forest Land	decreasing	RR, LM	no	no	no
I2/F4	Forest Land (Cat. A)	constant	PA	no	no	no	Non-forest Land	decreasing	RR, LM	no	no	no
I3/F4	Forest Land (Cat. B)	constant	PA	yes	yes	no	Non-forest Land	decreasing	RR, LM	no	no	no
I4/F4	Non-forest Land	decreasing	RR, LM	no	no	no	Non-forest Land	decreasing	RR, LM	no	no	no

VM 2.4 Analysis of historical land-use and land-cover change

VM 2.4.1 Pre-processing, VM 2.4.2 Interpretation and classification, and VM 2.4.3 Post-processing.

Land cover change data exist for 1990, 2000 and 2005, via analysis of Landsat-5 data for the entire reference area (VM Table 5). The result is a map of cover and change for forest, non-forest, water and cloud over the three time periods, with less than 8 percent cloud cover in any time period. Change rates are calculated in percent per year for areas that were cloud-free in both dates in question. A maximum forest cover map for 2005 was produced using all dates of imagery, i.e. filling in cloudy areas in 2005 with classifications from earlier years, if not forest.

The land-cover change analysis is based on traditional methods of remote sensing analysis that have been applied successfully in many tropical forest regions. The analysis and data have been published in two studies. The first was conducted by Harper, *et al* (2007) and included 1990 and 2000. The second analysis used the same methodology but covering the year 2005 (Jariala 2009), completing a 15 years change analysis with forest visible at three dates period: 1990, 2000 and 2005. For further details on pre-processing, interpretation and classification, and post-processing steps, refer to Harper, *et al* 2007, Jariala 2009 and Supplementary Information – Land cover and land change analysis for CAZ.

At the end of step 2, a series of maps for the reference region and project area were produced from this analysis, as required by the methodology. Forest cover benchmark maps for the first and the last date analysis are shown below in Figures 12 and 13. The Forest cover benchmark map of 2005 (Figure 13) also represents the Land Use and Land Cover map of 2005. Deforestation for the two sub-periods analyzed (1990-2000, and 2000-2005) are presented in Figures 14 and 15 respectively. The Deforestation map for 2000-2005 also represents the Land-Use and Land-Cover Change map for the most recent period analyzed. A Land-Use and Land-Cover Change Matrix for the most recent period analyzed is also shown in Table 8. The GIS files are provided with the VCS PD to the validators.

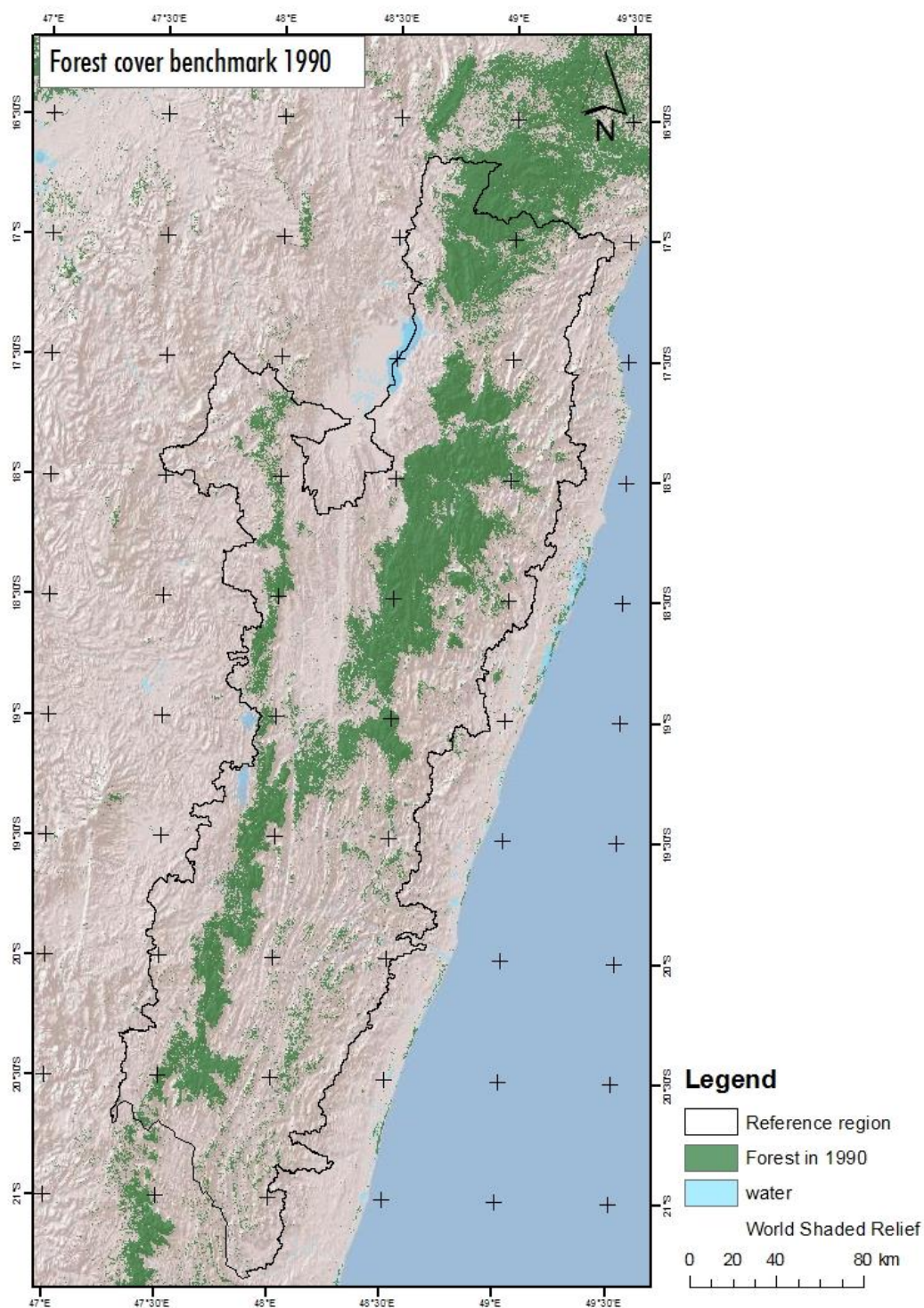


Figure 12. Forest cover benchmark map 1990

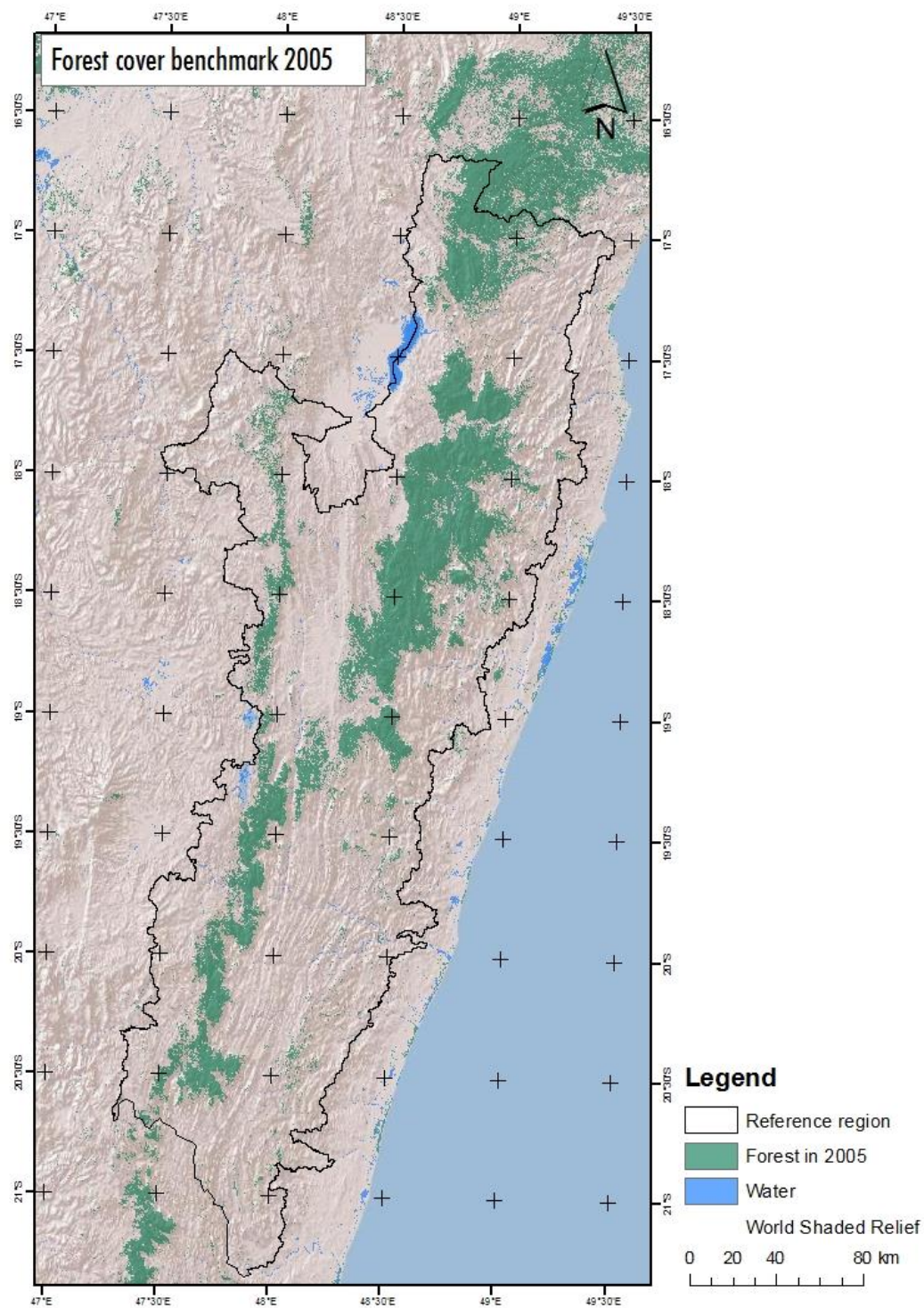


Figure 13. Forest cover benchmark map 2005, and land Use and Land Cover map 2005

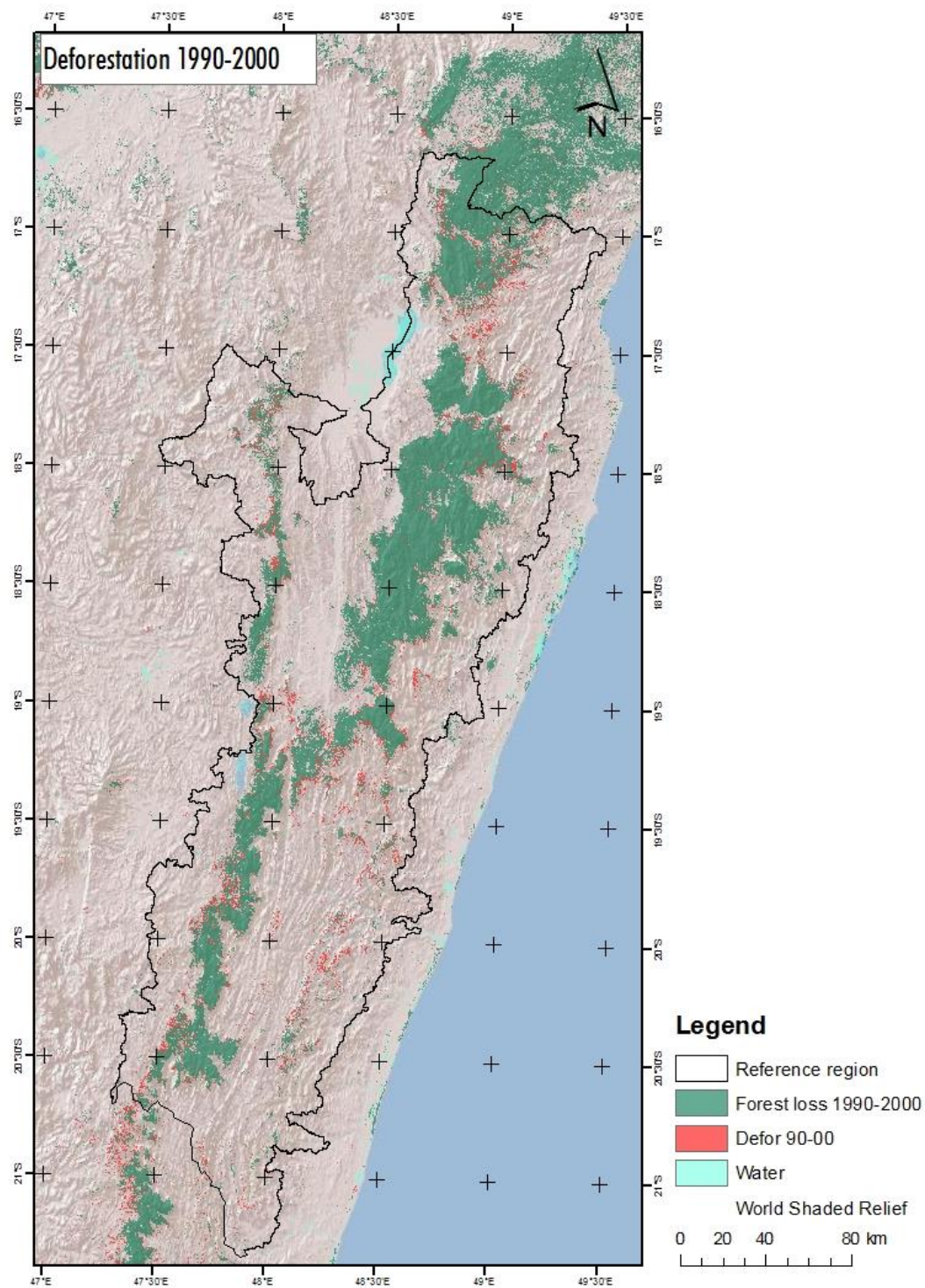


Figure 14. Deforestation map 1990-2000

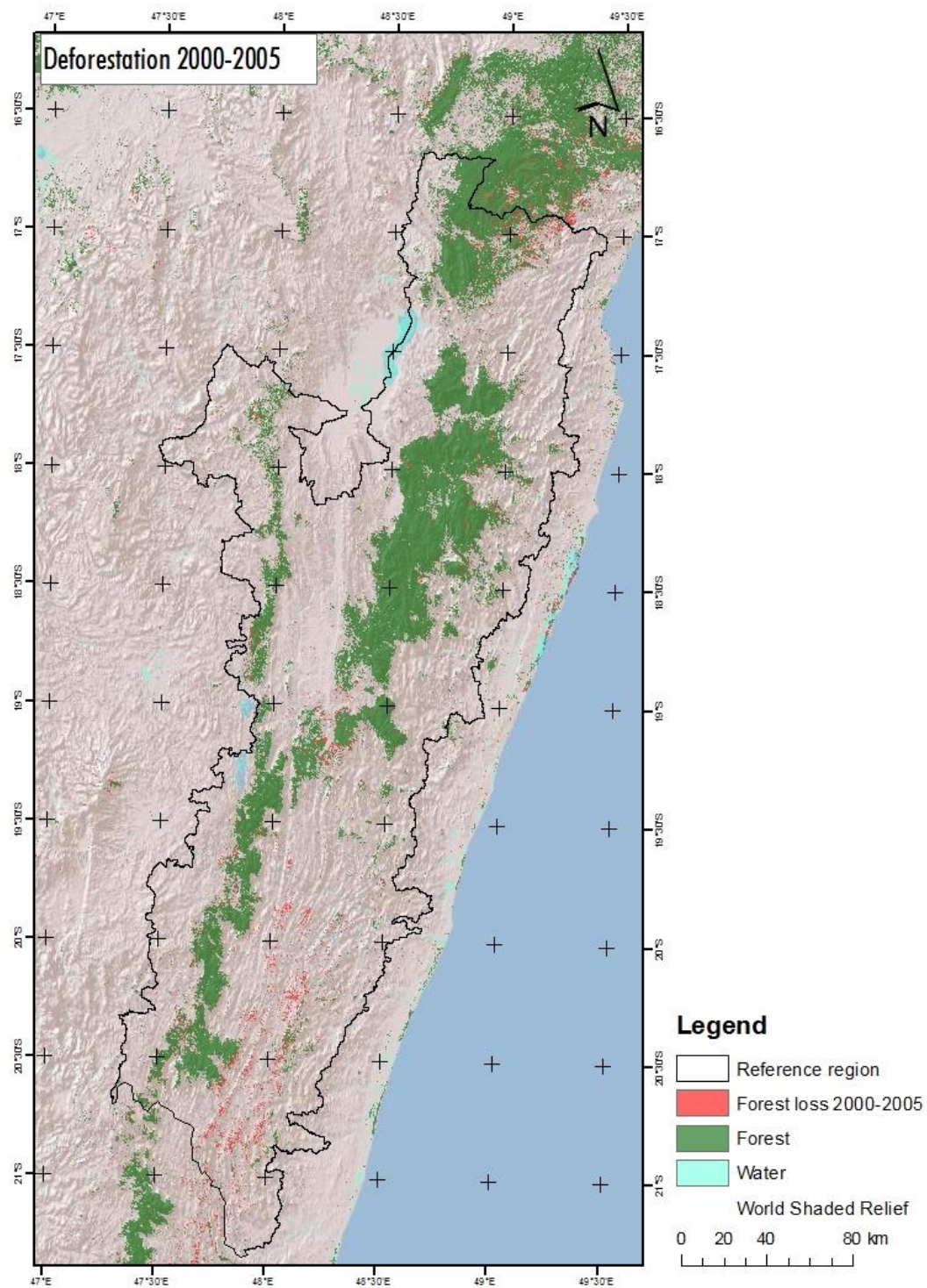


Figure15. Deforestation map 2000-2005

Land use land cover change matrix: shows the area in hectares of each forest class converted to non-forest in the reference region during the last period analyzed 2000-2005.

Table 7. Land use land cover change matrix (2000 – 2005) in ha

Land-use land-cover change matrix (2000 - 2005) in ha*		
initial \ final	Forest land	Non-forest Land
Forest Land	1,006,426	0
Non Forest land	26,695	3,783,079

*for simplicity the three forest classes of Figure 11a have been combined into a single forest class for this table.

VM 2.5 Map accuracy assessment;

The data used for 1990 and 2000 in the land cover change analysis comes from a study by Harper et al. (2007), who verified the accuracy of the map as follows: *“We collected GPS-linked digital photography and video imagery during five days of low altitude flights in September 2002. We used one subset of these data to assist interpretation and another to estimate the accuracy of our c. 2000 classification. Based upon our error analysis of 342 areas distributed among the three forest zones, we estimated 90% accuracy in identification of forest and non-forest. To directly estimate the error of our deforestation class would have required two dates of validation data, corresponding to the two dates of satellite imagery in question, but this was unavailable.*

The error in the deforestation class is not the product of the error for forest and non-forest in the two dates of classification because we conducted a direct multi-temporal classification. We believe it is reasonable to assume that the error rate for the deforestation class was about the same as the error rate for the forest and non-forest classes.

The c. 2000 data showed a total 89 800 km² of forest, with an estimated accuracy of about 90%.”

Since the overall accuracy is 90% and forest is 90%, we can assume that the accuracy for non-forest is higher than the 80% required by the methodology.

To assess the accuracy of the forest cover map for the 2005 data, a set of 250 points was sampled, distributed across the reference region. A visual interpretation of the land use land cover of each point using high resolution images available on Google Earth (Quickbird, 5m spatial resolution) was performed, and the results were compared with the supervised classification. Two types of precision/error (user accuracy and production accuracy) were computed and the overall map accuracy was calculated as the average of these two measurements.

- The user accuracy (Pu) showing the percent of classified pixels that were correct in the field/reference. This is an accuracy measure from the user’s perspective: “If I select any forest pixel on the classified map, what is the probability that I’ll be standing

in a forest stand when I visit that pixel location in the field?” It is computed with the formula:

$$P_u = \frac{\text{number of pixels classified correctly}}{\text{number of reference pixels}} \times 100$$

- The production accuracy (Pp) indicates the percent of pixels from the field that are correctly represented on the map. It is an accuracy measure from the producer’s perspective: “If I know that a particular area is forest what is the probability that the digital map will correctly identify that pixel as forest?” It is computed using the formula:

$$P_p = \frac{\text{number of pixels classified correctly}}{\text{Total number of pixels classified}} \times 100$$

From the 250 randomly created point, six points that were covered by clouds in either high resolution images or interpreted in the supervised classification we removed, leaving the sample with 244 reference points distributed over the reference region.

The confusion matrix below summarizes all of the accuracy parameters for each class in the last cover maps (2005). The table shows that the overall accuracy of the forest cover benchmark map is 96% (Table 9).

Table 9. Accuracy of the land use classes classification

High Resolution images (Google Earth)						
Supervised Classification		forest	non forest	water	Total	User’s accuracy
	Forest	50	4	0	54	92.6
	non forest	4	184	0	188	97.9
	water	0	0	2	2	100.0
	Total	54	188	2	244	
Producer’s accuracy		92.6	97.9	100.0		96.7Overall accuracy

2.6 Preparation of a methodology annex to the PD

A detailed description of the remote sensing methodology and procedures used to classify the satellite imagery is provided to the validators as supplementary information, as well as reported in Harper, *et al.* 2007. These publications describe the pre-processing, classification methods, post-classification processing, accuracy assessment steps followed and the image sources used.

VM Step 3: Analysis of agents, drivers and underlying causes of deforestation

VM 3.1 Identification of agents of deforestation

This project defines one main agent of deforestation - the small-scale subsistence farmer. These are by far the dominant agents of deforestation in the region and are expected to be in the coming decades.

Name	Small scale, subsistence farmers
Description	The population of the region is largely rural and dependent on subsistence farming as their principal livelihood. According to the ILO census of 2001, the population of the Alaotra Mangoro Region was 978,272, of which 82% were rural. Slash-and-burn agriculture – called <i>Tavy</i> – is a traditional technique favoured by the people of the region. Some farmers may practice <i>Tavy</i> exclusively. The primary crop in <i>Tavy</i> is rice, often with cassava, or vegetables. A common scenario is for a <i>Tavy</i> farmer on steep slopes to plant rice for a couple of years, then, as soil nutrient concentrations drop, shift to cassava. As nutrients are depleted further, the land may be left in fallow for a number of years and returned to another round of production, this time at lower yields. On moderate slopes, <i>Tavy</i> yields may diminish by 50% after 3 years of cultivation, and on steep slopes <i>Tavy</i> yields may fall by 50% within two years (Styger et al. 2007). When land is in short supply, the fallow period is reduced, and the soil is rapidly degraded. At some point the land may be used for grazing or similar low-productivity use, or it may be cropped continuously until it is exhausted and abandoned, and the <i>Tavy</i> farmer may look for more forest to repeat the process. <i>Tavy</i> farmers, working on high, steep, remote hills, tend to be isolated from large villages and markets, so grow crops for subsistence, primarily rice and cassava. Especially in isolated areas with limited markets, crops are grown in accordance with a concept of requirements. A farmer practicing <i>Tavy</i> will farm as long as necessary to grow a certain amount of food for household consumption and limited trade, and not necessarily more. Soil nutrients generally decline in <i>Tavy</i> lands under cultivation. Studying plots in eastern Madagascar, Brand (Brand and Pfund 1998) showed that soils planted in an upland rice-fallow system show declining concentrations of nutrients. In long-term shifting cultivation, the soil nutrient stock may fall by a third, and over a longer period of intensive use, the soil may lose more than 90% of the nutrient concentration of soils in rainforest, and support only grass. Recovery of nutrients in fallow upland is very slow, starting to increase after 3-5 years of fallow (Brand and Pfund 1998).
Population	The population growth rate of Madagascar in rural areas is 2.4% (World Bank, 2012).
Historical	Historically the main cause of deforestation in Madagascar is the clearing of forests for cultivation by <i>Tavy</i> . (for example, see

deforestation	Green and Sussman 1990; Dufils 2003). A report on forest cover change for a control area within the larger eastern forest corridor was completed by Hawkins and Horning (2001). The study compared satellite imagery from November 1994 and April 2000. Within the corridor studied (an area of about 4,100 km²), 6.7% of the area was deforested in this time period. This represents an average annual deforestation rate of 1.1%, where forest is defined as an area of trees greater than seven metres in height with greater than 30% crown closure. Historical deforestation rates within the eastern rain forest corridor were also documented by Green and Sussman (1990). Through an analysis of historical Landsat images, they concluded that rain forest deforestation rates in the eastern rainforests occurred at a rate of about 2.5% between 1957 and 1973, and a rate of 0.8% between 1973 and 1985. More site-specific forest cover studies were conducted near Andasibe, close to Analamazaotra Special Reserve and within the corridor, (Horning, 2000). Four sub-areas in this area were evaluated for forest loss between 1993/94 and 1997/98. Annual forest loss was estimated at 1.0%, 1.0%, 1.5% and 5.6% in the four sub-areas studied. These trends reflect the conversion of primary forest to Tavy areas.
---------------	---

There are other potential agents of deforestation and degradation in the reference region but according to expert opinion these do not cause significant deforestation in comparison to Tavy (e.g. see Jariala (2007) report on expert workshop on the causes of deforestation in Madagascar and the CAZ management plan and the Supplementary Information Impact of legal and illegal harvesting on forest degradation in the CAZ REDD project area) but are mentioned here so that a fuller understanding of the historical and regional LULC change can be gained. Since they are not considered to be important agents of deforestation in this part of eastern Madagascar, they are not considered “identified agents of deforestation” and are therefore not considered further in subsequent analyses.

They are as follows:

1. Charcoal production
2. Small-scale logging
3. Illegal small-scale mining
4. Mineral prospection and large-scale mining

Name	Charcoal producers
------	--------------------

Description	In the eastern region of Madagascar, charcoal is produced from eucalyptus plantations in the vicinity of the main roads, particularly the RN2 to the south of the project; it is not widespread activity elsewhere in the corridor (e.g. see CAZ management plan) and does not cause deforestation of natural forest in this area. Charcoal making is done both by independent operators and by wage labourers. Most wood cut for charcoal comes from private eucalyptus plantations planted in strips of several kilometres along both sides of the railroad that runs between Antananarivo and Toamasina (Montagne et al., 2010).
Population	During the social safeguards analysis, no-one was identified as being involved in charcoal production in natural forests in the villages around the project area (Source: Plan de Gestion Environnementale et Sociale de CAZ, 2012).
Historical deforestation	No significant clearing of natural forest has taken place in the last twenty years for the production of charcoal as it is produced by the rotational harvesting of existing eucalyptus plantations. Within the region of the corridor, these were historically established on existing deforested lands, which had already been deforested by Tavy. In the area surrounding CAZ, charcoal production is localised along the main road, Route Nationale 2, and the rail line running from Antananarivo to Toamasina. Historically these Eucalyptus plantations were planted in the first half of the 20 th century to supply wood to steam trains (Montagne et al., 2010).

Name	Small-scale loggers
Description	Small-scale logging is selective and mainly for general timber for local use but also some logging occurs for hardwoods, particularly palissandre (COGESFOR 2010, Supplementary Information - Impact of legal and illegal harvesting on forest degradation in the CAZ REDD project area). In the past, private logging companies have held small logging concessions (ca. 100 ha) on the western and southern edges of the corridor (for example, Beparasy, Lakato, Didy Anosibeanala and Ambodivatot) and historically some logging for local use has occurred in most of the accessible areas of the corridor. In the 1990's most of such logging was done legally; but in 2002 the government stopped the issue of any further logging permits. Some logging has continued illicitly since that time (CAZ management plan). Most forest enterprises are small scale and there are no large logging companies in Madagascar. Producer groups and companies are ill-equipped and undercapitalized, and many workers are part-time farmers using tree harvesting to supplement subsistence agriculture. Tree-cutting and squared timber sawing are typically done with the hand tools in the forest. Hauling is done on man's back and transportation towards industries and markets is carried out by low volume individual transporters. As a result of this inefficient harvesting and transportation system, a good part of sawing is also done in the forest and is extremely wasteful. Gathering of non-wood products, as well as timber production and skidding, are done manually. According to Malagasy law, logging concession holders must reforest areas that they have logged.

	The town of Moramanga is a regional center for forestry operations of the Fanalamanga company, the state owned forestry company that owns and is responsible for managing the pine plantations that are found to the west of CAZ. Forestry companies in the region are geared towards operations in these plantations.
Population	During the social safeguards assessment for the project, no-one was identified as being dependent on small scale logging activities in the CAZ for their livelihoods (Plan de Gestion Environnementale et Sociale de CAZ - 2012). Most people living near forests will take some wood for their own use
Historical deforestation	No past analyses have identified logging to be a cause of significant deforestation in the CAZ area due to its selective nature (e.g. MINENVEFT et al., 2009; Jarijala, 2007). .

Name	Small scale illegal miners
Description	Most mining for gold in Madagascar is by small mining companies and artisanal miners. Illegal small-scale mining activities can contribute to forest degradation in Madagascar but the areas affected are small compared to the problem of Tavy. The eastern rain forests are exploited for gold, quartz and semi-precious stones. The mining administration does not have the means to control these illegal activities and enforcement of existing laws is very limited. This is particularly true when there are rushes to a productive site. The nature of small scale mining makes it impossible to predict where when and the extent that illegal mining activities might impact forests and biodiversity.
Population	No historical data exists on the number of people involved in small scale mining/prospection. Past experience of mining rushes for precious stones at several sites including in or near protected areas (e.g. Ankarana and Isalo) have resulted into tens of thousands of people moving into an area (Tilghman et al, 2007). In April 2012, a similar rush for sapphires occurred within the CAZ project area in an area most easily accessed from the commune of Didy. Sapphires had not previously been known from the area and so this event was impossible to predict. Detailed information on the numbers of people that were involved in this rush are not available because of the speed with which it happened and because migrants coming from outside the area was very dynamic with people arriving and leaving constantly over several weeks (CI's personal communications with the local Director of Forestry /DREF and Community associations/VOI). Several operations by the police and forestry agents to remove people also contributed to keeping the miners mobile and difficult to count. Many of the people initially encountered in the forest were also from local communities rather than migrants coming into the area (CI's personal communications with the local Director of Forestry /DREF and Community

	associations/VOI). . Although initial estimates and figures recorded in the media for the number of people involved in this “sapphire rush” were highly variable, there were probably 5000-10000 people involved (Pardieu and Rakotosoana, 2012). From July-September 2012, several smaller operations organized by the Forestry department and local gendarmes (police) removed miners and turned many away from the site (CI’s personal communications with the local Director of Forestry /DREF and Community associations/VOI). However the multiple access points to the forest and relatively small number of officers available meant that the situation was not contained. Following a request from the forestry and mining departments, the central government organised a military operation to remove miners in an operation in June 2012 (Pardieu and Rakotosoana, 2012; http://www.lexpressmada.com/saphir-didy-madagascar/35519-les-exploitants-illicites-deloges.html). This operation was successful and the great majority of miners have left the site. In addition, by this time few new sapphires were being discovered (Pardieu and Rakotosoana, 2012) and conditions in the forest were very difficult for miners (several deaths occurred during this sapphire rush) and this probably contributed to many people’s willingness to leave when ordered to do so by the military. Other sapphire sites in Madagascar are well known, tolerated by the authorities and are probably less dangerous and an easier prospect for migrant miners. It is likely that smaller number of miners will continue to pose an ongoing threat to CAZ but the small numbers and methods used mean that the threat is not likely to result in deforestation but very localized forest degradation and localized threats to biodiversity from subsistence hunting. We conclude that the threat from small scale mining is not an important deforestation driver. The great majority of small scale mining does not result in deforestation. A larger “rush” such as that observed in July 2012 is an unusual and unpredictable event (indeed this was the first time such an event is known for the CAZ area) that will result in deforestation but it is impossible to predict the magnitude of this since it depends on the numbers of people involved and the speed with which the authorities react to control the situation. This type of event is therefore best considered as a unpredictable threat that needs to be monitored and quantified in the event of it occurring.
Historical deforestation	Past analyses of deforestation have not judged illegal small scale mining to be a cause of significant deforestation (Messerli, 2004; Jariala (2007); Moser, 2008; MINENVEFT et al., 2009). Most artisanal mining takes place along water courses or is concentrated over small areas of forest, which may or may not be cleared to facilitate access to the minerals. The deforestation that it causes is insignificant in area compared to Tavy. Impacts of mining are more important in terms of hunting of biodiversity and the impact on water quality. Exceptionally, larger mining rushes for precious stones such as sapphires have the potential to cause greater damage, including

	localized deforestation. Such an event did occur in 2012 and was eventually controlled by the authorities. Given the unpredictable nature of such events, deforestation from such “rushes” is better considered as a risk for the project, the impact of which needs to be monitored and quantified in the event that it happens.
--	---

Name	Large-scale mining
Description	CAZ encompass a variety of geological formations that have potential mineral deposits, some of which may present potential opportunities for industrial mining. Prior to the initiation of the CAZ project, the government could have designated parts of the project area for mineral prospection. The project development period from 2004 onwards coincided with a period when the Malagasy government authorized mining prospection over most of the country. Natural forests were mostly excluded from these new authorizations (e.g. see the Arrêtés related to protected areas and sustainable management of forests provided as references). Some prospection blocks had already been acquired by mining companies, with the eventual possibility of mining commercially-viable deposits (e.g. see Figure 29). However as part of the CAZ project development these mining permits were revoked, sometimes in exchange for mining permits elsewhere in the country. Two mines have been developed as commercial operations in the region. Both are outside of the project area (southwest of the main corridor) and will not impact the project negatively. Ambatovy mine is a large nickel and cobalt mine that will operate from 2011 for 30 years (see www.ambatovy.com). The graphite mine at Mantadia is currently inactive, apparently because it is no longer commercially viable. No expansion of either of these mines is planned and no further unplanned deforestation is expected at them. Madagascar has important mineral resources spread throughout the country. While in 2006, mining activities represented about 4% of the GDP, the government of Madagascar estimated that and in its national development plan, planned for it to contribute at least 30% by 2011 if all existing reserves were exploited (Government of Madagascar, 2006). Mining is part of the government’s stated strategy for economic development.
Population	Some people living around CAZ benefitted from short term labour during the period of constructing the Ambatovy mine. Most jobs during the production phase will not initially be for the local people but this may change over the 30 years of the project as mining skills are transferred to the local workforce.
Historical deforestation	The Ambatovy mine has a total mine foot print of 1,326 ha (Dynatec, 2006). This deforestation is not in the project area.

VM 3.2 Identification of deforestation drivers

The project identifies the population of rural farmers using *Tavy* as the main agent driving deforestation. The driver variables explaining the location of deforestation are: access to the forest, access to markets, altitude and the related climate conditions, and terrain that determines the suitability of the land for conversion to crop land. Populations, forest access and market access would be expected to increase in the future in the baseline case. The bio-physical variables (altitude, climate and the availability of suitable terrain) are not expected to limit deforestation in the foreseeable future as farmers are able to evolve their production systems to all of the environments existing within the forest corridor.

Note that the following section provides an analytical description of the drivers and their impact based on expert knowledge of the region. However such an analysis as requested by the methodology cannot adequately describe the interactions and correlations between these different variables. A more quantitative analysis thus using modelling is also conducted to better understand how different variables affect the location of deforestation and is described in subsequent sections.

Driver variables explaining the quantity (hectares) of deforestation

Key driver variable	Impact on deforestation agents	Likely future development	Project measures
Agricultural population density	Population growth in the rural regions to the west and east of the corridor has led to a 'saturation' of valley floors most suited to irrigated rice cultivation / paddies, as well as upland rice areas. This pushed younger and landless families to move into the forest corridor to seek out unexploited land, where they converted the valley floors to rice paddies and deforested the surrounding hillsides by <i>Tavy</i> . After several cycles of	Population density is likely to continue increasing on both sides of the corridor, increasing demand for both land and other forest resources. Pressure to deforest land will increase over time.	Through the project, better enforcement is being put in place to protect the forest from illegal clearing. Use rights for the forest by local communities are also improved to provide them with security for access to these resources and a long term stake in seeing improved management. Finally, the project provides opportunities to improve the agricultural techniques used so that production can be more intensive and

Key driver variable	Impact on deforestation agents	Likely future development	Project measures
	<i>Tavy</i>, and over a period of several decades, these areas can become unproductive grasslands. The small isolated families grew in size to small hamlets located within the forest. Farmers converted the forest environment to one that is more favourable to farm production, reducing the forest area within their vicinity and fragmenting the forest on a landscape scale. Population growth is therefore thought to be an important driver of deforestation. Such a dynamic is still valid today, with landless families seeking out new opportunities within the forest. Farmers also use <i>Tavy</i> to establish tenure over land for future generations. Growth of a subsistence population that is dependent on the clearing of new forest to maintain output will drive the continued deforestation of available forest land.		incomes more diversified, thus reducing the need to clear new land.

Driver variables explaining the location of deforestation

Key driver variable	Impact on deforestation agents	Likely future development	Project measures
Access to forest from existing villages	Distance from villages is the most important predictor of the location of deforestation (see section 4.2).	Villages close to the forest are likely to increase in size, hamlets will become villages and new villages may potentially be created	The emphasis of protection measures as described in section 1.8 is through self-enforcement by the villagers themselves through community management contracts and a variety of incentives. This is because the source of potential new deforestation will be the villages that are closest to the forest edge.
Access to forests (distance from villages, railways, roads, footpaths and navigable rivers)	Access is an important factor in deforestation in Madagascar, with proximity to roads in eastern Madagascar stimulating higher deforestation (Kistler and Spack 2003). Gorenflo et al. (2011) found a strong relationship between deforestation and distance from footpaths, distance from roads, and slope – all measures of accessibility – suggesting that deforestation is less likely in places more difficult to reach.	There are no planned new roads or railways in the project area. Construction of new roads for the Ambatovy mine is outside of the project and will not affect the project area. Access to forests from existing villages close to the forest will be the most important factor predicting location of deforestation. There will be no change in access via rivers.	Access to the project area through existing footpaths will be regulated through the conservation agreements with the communities. Access to the forest by larger forestry tracks will be blocked.
Access to forests (slope)	The loss of lowland and coastal rainforest in Madagascar has been attributed in part to its topographical	No change	As above

	accessibility (Green and Sussman, 1990; de Gouvenain and Silander, 2003). Subsistence farmers of the region use <i>Tavy</i> to cultivate extremely steep slopes (40 degrees) (Moser, 2008) and it is unlikely that the slope of a hillside will prevent a farmer practising <i>Tavy</i> if its soil and orientation are suitable		
--	--	--	--

VM 3.3 Identification of underlying causes

The underlying causes of deforestation of the eastern rainforests include the following (Gorenflo, 2011 and references cited therein):

1. reliance on unsustainable *Tavy* cropping systems that give declining returns to labour and require new deforestation to maintain productivity;
2. rural people have no opportunity and little incentive to intensify and diversify agriculture and rural production systems away from the use of natural forest land and resources;
3. conflicting customary and state-defined land tenure, combined with poor enforcement, means that clearing forest is a low-cost way of gaining new land, but at the same time there is no strong incentive to invest in improving the agricultural productivity of land of insecure ownership;
4. poor forest governance makes the unsustainable exploitation of forests the most economically rational path;
5. a rapidly growing population; in urban areas this increases the demand for food and forest products; while in rural areas it increases the demand for land.

Key underlying cause	Impact on deforestation drivers & agents	Likely future development	Project measures
1. Unsustainable agriculture	In order to increase production, farmers must expand their lands. As productivity	With the rural and urban population of the region set to continue growing, the	The project aims to increase the sustainability and productivity of

Key underlying cause	Impact on deforestation drivers & agents	Likely future development	Project measures
(reliance on Tavy cropping systems that give declining returns to labor and require new deforestation to maintain productivity)	of old clearings rapidly decreases due to the loss of soil fertility, expansion takes place by clearing forest (Styger et al., 2007). During the decade from 1990 to 2000, 1,620,000 ha of forest were lost (Steininger et al. 2003) while per capita agricultural production (mostly rice) has fallen by about 1% every year since 1960 (World Bank, 2010).. Stagnation or reduction of agricultural productivity in Madagascar has been noted for several years under traditional agricultural systems. The shifting cultivation systems practiced in the area around CAZ have been demonstrated to lead to soil degradation and nutrient loss, which in turn reduces crop yields and leads farmers to clear forest for new fields (Styger et al. 2007, Styger et al. 2009). According to a 2009 FAO report, the agricultural production index per person has continuously decreased, from a high level of about 131 between 1979 and 1981 to 91 in 2003 before a slight increase to 96 in 2004. Efforts to improve productivity generally focused on	demand for land and agricultural products will become stronger. Farmers of the region will continue to use Tavy, despite the regulations and development efforts to shift agriculture away from it. There are good reasons for this: • It is a sure and robust form of production, well suited to the steep slopes, rainfall and wind; and has a yield per unit labour that is comparable to or better than other systems. • It is a critical form of insurance against the loss of harvest of paddy rice and other crops grown that are vulnerable to flooding. For this reason, even those families with rice paddies will practice it. • Tavy is an integral part local people's culture. • It is practised even by those wealthier families who own rice paddies because it complements the harvest calendar of other	agriculture with the objective of reducing the need for new land for Tavy as described in section 1.8 . The empirical evidence suggests that this logic is valid in rural Madagascar: increases in rice yields result in lower rates of deforestation. Similarly, higher soil fertility implies lower rates of deforestation. The project will therefore promote alternatives to Tavy (as described in section 1.8) and at the same time accompany these with measures to increase enforcement so that clearing new land is not a free option. These measures include establishing a protected area, putting in place community forest management contracts and linking development assistance to forest conservation results.

Key underlying cause	Impact on deforestation drivers & agents	Likely future development	Project measures
	relatively accessible areas – which are often far from forests.	crops.	
2. Lack of economic opportunities other than agriculture and forest exploitation, combined with insufficient efforts to intensify and diversify agriculture and rural production systems	About 81% of Madagascar's households lived on less than \$1.25 per day in 2011 (World Bank, 2012) and about 82% of rural households were classified as poor in 2010 by the national statistics agency (INSTAT, 2010). Poverty is most pronounced in households whose primary revenue comes from agriculture, particularly smallholder farmers. . This is true of the project area, where the livelihoods of local people are mostly based on subsistence agriculture and extraction of forest products. There are few opportunities to earn money. The population surrounding the project area typically has no access to technical assistance in the form of agricultural outreach services, health care, credit and most areas do not have good access to markets for cash crops. Communities who have access to both markets and remaining forest areas will rationally convert forest so that they are able to expand their landholdings and	The socio-economic conditions of the communities are not likely to change and they will continue to depend on <i>Tavy</i> and forest exploitation as a means of living. In the future, the local economy will not be diversified away from agriculture and forest exploitation on a broad enough scale to decrease the loss of forest by providing alternative employment. The historical pattern has been for people to exploit and convert all forest land available to them; at this point they themselves evolve their production systems in order to cope with no more forest land being available. It is unlikely that they will start to use sustainable production systems before there is a broadscale loss of forest. Even if alternative, sustainable systems are promoted to local people, their most rational course is to exploit available forest as long as	Opening markets and increasing the productivity of agriculture will reduce the impact of each individual farmer on deforestation. At the same time the cost of clearing forest will increase due to the improved enforcement that the project brings. The clearance of new forest must be stopped and land use stabilised. The project will achieve this through the establishment of a co-managed protected area and community forest management contracts with the local communities. Agricultural expansion is negatively related to rice yield (higher yields of rice imply lower rates of deforestation), and soil fertility (higher soil fertility equates with lower rates of deforestation). To this end the project is providing financial and technical support to farmers that will enable them to intensify, diversify and improve the productivity of their production systems.

Key underlying cause	Impact on deforestation drivers & agents	Likely future development	Project measures
	supply nearby markets.	penalties for doing so are not imposed. The urban market demands that are causing forest loss in the areas close to roads will continue to grow. In the long term the Ambatovy mine will create non-agricultural employment for people in the south of the corridor. However, this will only provide a direct opportunity for a relatively small number of people. Nevertheless it does also create a market demand for additional services such as the provision of agricultural produce and this is a potential opportunity for the communities living around CAZ.	
3. Land tenure policies and their enforcement	Land tenure in Madagascar is based on the principle of state ownership: the State owns vacant or unregistered lands. The only recognized and guaranteed property is private property that has been officially registered through proving actual, obvious and permanent personal hold and <i>valorization</i> for at least ten years, after which it can be considered an appropriation.	Prior to the 2009 political crisis, Madagascar had been making good progress on simplifying the process of getting land tenure and in making this service more accessible for the rural population. However, although the necessary legislation and procedures are in place, the suspension of several major aid programs has stalled this process to some extent. Nevertheless, in the long term it is likely that rural	The implementation of a protected area and community forest management contracts to clarify and secure land tenure throughout the project area and surrounding areas. The project will also encourage local people to obtain title of their existing land. This will only be possible in areas where there are cadastral services, but

Key underlying cause	Impact on deforestation drivers & agents	Likely future development	Project measures
	Outside of the official system, customary tenure rights continue to function, particularly in rural areas. While customary tenure is respected by local people, it is not recognised in the official system or by immigrants. On the otherhand, rural people often do not understand or are not even aware of the official system. This system has prevented the vast majority of farmers from gaining legal rights to their land. After more than a century of the state ownership principle, barely 10 % of the territory has been registered (Government of Madagascar, 2006).	people will be able to clarify their land tenure more easily and this should provide much greater land security for the people living around CAZ.	these are expanding in Madagascar and the project will lobby for improvements in these services for communities around CAZ.
4. Poor forest governance	Poor governance in the forestry sector is a fundamental problem in Madagascar (R-PP, 2010; Jariala 2005) and this holds true for the region of the project area. Examples of poor governance cited by the World Bank (2003) include: awarding forest clearance permits for maize farming; the availability of blank permit books used by ministry officials etc. For decades, illicit appropriations of forest	There are no signs that the necessary resources for improved governance will be available without projects such as the one being proposed for CAZ. For example, in the \$52 million extension of phase 3 of the environment program, (World Bank, 2011) forestry reform was not even included in the project. USAID, another donor that had	Implementation of a protected area and community forest management contracts to clarify and secure community access to forest resources throughout the project area. The project plans to use part of the revenues from VCU sales to ensure that the necessary resources are available for enforcement activities.

Key underlying cause	Impact on deforestation drivers & agents	Likely future development	Project measures
	goods and incomes by political and administrative authorities at the local and central levels have integrated into the normal administrative management system. A high level of tolerance for petty corruption and offenses of the forest code exists at the level of forest and non-forest national institutions. The national capacity for law enforcement has not been adequately strengthened despite significant investment by the World Bank and USAID through the environment program (Jariala 2005 report).	supported this reform in the past has closed its environment program in Madagascar altogether (USAID 2010).	
5. Rapid population growth	Madagascar's rapid population growth, estimated at 2.86 % annually (World Bank, 2012), is the main factor contributing to a significant increase in demand for both subsistence and cash crops. Free access to resources (and to forest lands) increases the impacts of population growth on deforestation. In order to keep food production up with population growth, farmers have increased production through area expansion, resulting in massive	The Malagasy population of 20.7 million people is 70% rural but a steady migration to towns and cities over the last 20 years means that the urban population growth rate is higher than the rural rate (4.0% versus 2.4% in 2011; World Bank, 2012). Population projections prepared by the United Nations for 2050 range between 37 and 51 million, depending on assumptions of mortality and fertility (United Nations Population Division	Improved security of access to forest resources by the existing communities and improved enforcement will make clearing of new land less attractive. The project has also promoted family planning efforts to allow women improved choice. Although family planning will not be a formal part of the project, other projects and government initiatives will be encouraged to work in this region.

Key underlying cause	Impact on deforestation drivers & agents	Likely future development	Project measures
	deforestation and significant biodiversity loss in Madagascar over the last 40 years. With adequate fallow periods, shifting agriculture can allow previously used fields to regenerate their nutrients before they are farmed again (Styger et al. 2007). However, increased population in particular areas has led to shortened fallow periods, causing soil exhaustion and requiring that farmers expand increasingly into natural habitat.	2005). Population growth for the two administrative regions that the project lies within is about 2.7% (INSTAT, 2010)	

VM 3.4 Analysis of chain of events leading to deforestation

The rural people of the region depend on farming (mainly subsistence) and exploitation of forest (non-timber forest products, timber, charcoal and artisanal mining) for their livelihoods, and have few alternative opportunities to earn a living (MINENVEFT et al., 2009; MINENVEFT & CI, 2012). The principal form of farming is *Tavy* (MINENVEFT et al., 2009; MINENVEFT & CI, 2012). The isolation of many farmers means that they do not have access to agricultural extension services, credit and markets required for them to intensify their agricultural production or diversify their livelihoods (Messerli, 2004; CI, 2012). Even for those farmers who do have these benefits, *Tavy* remains a useful form of production (Messerli, 2004). Furthermore, the *de facto* system of land tenure and the failure of forest governance mean that clearing forest is of low cost and so *Tavy* remains the most competitive system (Aubert et al, 2003; Messerli, 2004). It also means that *Tavy* is a way of claiming new land (Aubert et al, 2003; Messerli, 2004).

Bio-physical variables which determine suitability to agriculture (access and slope) reflect farmers' preferences of where to deforest (Moser, 2008). However, such bio-physical parameters will not limit deforestation to particular areas since all the forest is found within physical parameters similar to observed historical patterns of deforestation (see Section VM 1.1) and it is likely that the majority of the remaining forest area could be converted to cropland. The socio-economic conditions of local people and poor forest governance make the unsustainable exploitation of forest products the most rational use of forest for local people (MINENVEFT et al., 2009; MINENVEFT & CI, 2012).

Figure 16 below illustrates this chain of events leading to deforestation in CAZ through a conceptual model developed based on extensive consultation with local experts and stakeholders, following the Open Standards for the Practice of Conservation⁵. These consultations were part and fed into the development of the CAZ Management Plan. The Figure also illustrates how the project activities fit into the project's theory of change.

⁵ <http://www.conservationmeasures.org>

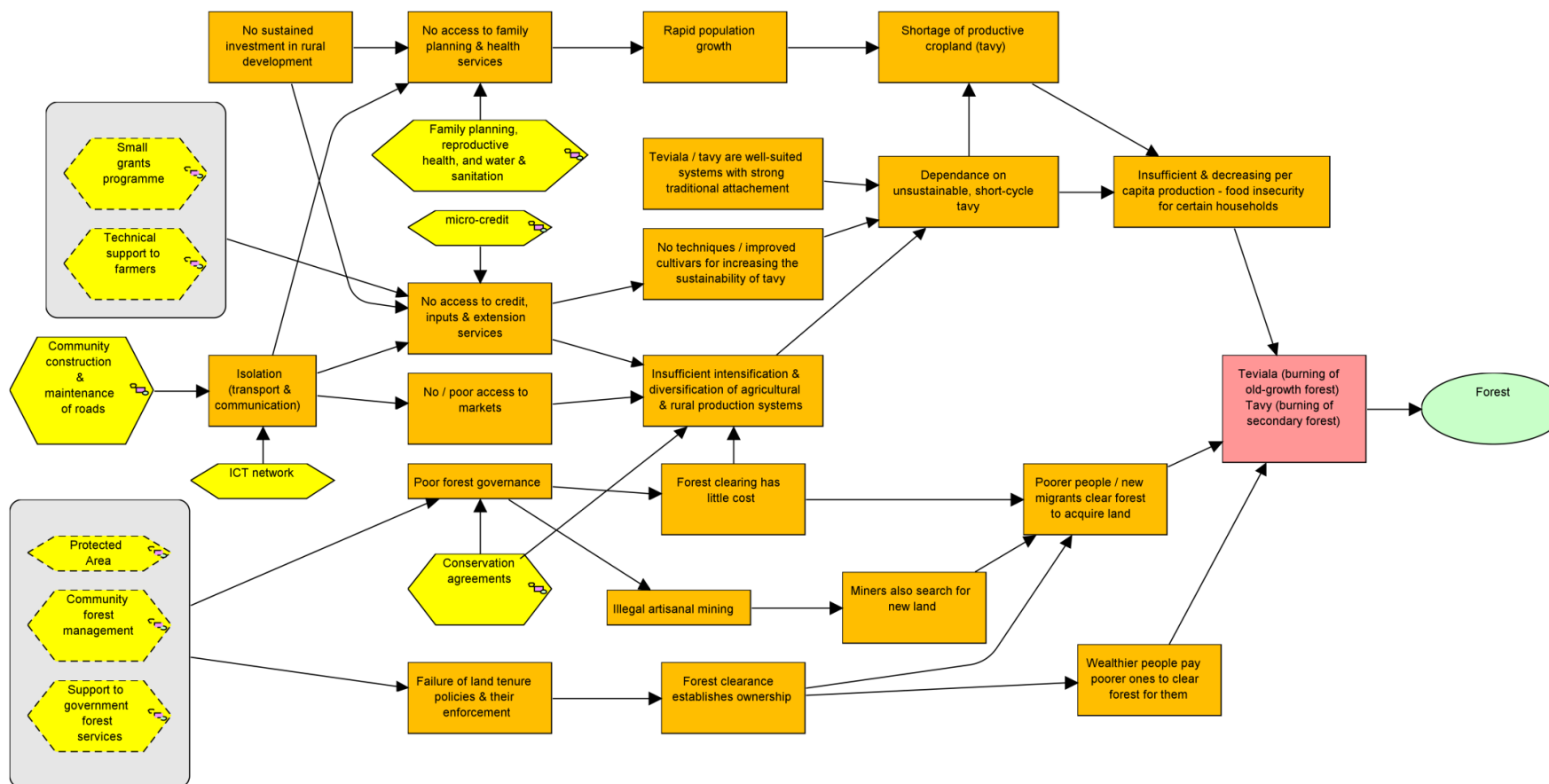


Figure 16. The underlying socioeconomic causes of deforestation and the project strategies to address these

VM 3.5 Conclusion

The underlying causes of deforestation can be summarised as:

- Tavy being an unsustainable yet well adapted form of production;
- a growing rural population dependent on Tavy and forest resources with few alternative economic opportunities;
- a system of land tenure and poor forest governance that make forest clearing and exploitation viable even though it is illegal under the forestry legislation;
- a growing urban population that is increasing market demand for food and forest products.

The sheer scale of fundamentally changing the socio-economic conditions of a large, dispersed and often very isolated rural population; rapid population growth; and continued political instability mean that over the next decades, the underlying causes of deforestation will continue to exist and to interact so as to favour and probably accelerate deforestation in the absence of the proposed project.

The main driver variables explaining the quantity and location of deforestation are:

- rural population density,
- access to forest from villages, roads and rivers; and
- bio-physical variables that determine the suitability of the land for conversion to cropland.

The first two of these drivers are expected to increase in the coming years, as the populations grows and transport infrastructure is improved in accordance with government policy of improving road infrastructure (Government of Madagascar, 2006). The present patterns of deforestation for cropland show: firstly, that there is still ample forest land suitable for conversion to cropland on hillsides; and secondly, that bio-physical conditions will not limit where farmers deforest.

Based on the evidence provided, we can therefore make a **conclusive** judgement that deforestation will continue in the reference region and the project area without the proposed project activities.

In addition, during the period of 1990-2005 some effort from the national government to halt deforestation was observed by increasing enforcement on the ground. However these actions did not continued after 2005, in particular, since 2009 after a regime change. Past experience shows that deforestation in Madagascar decreases during periods of strong regulation; and then suddenly increases as soon as the regulations are no longer enforced. Deforestation is also widely associated with political uncertainty.

Throughout the 1990-2005 period international donors made large investments in sustainable development and protected area management throughout Madagascar including the eastern rainforests. In parts of Madagascar that did not receive such investments, such as the southern and western spiny and dry forests, deforestation has not declined, rather it has maintained an even rate of around one percent a year since 1990 (MINENVEFT et al., 2009). No such future support is guaranteed and indeed all donor programs for the environment have ended as of 2011. The only exception has been a credit from the World Bank that will allow the government to continue management of part of the protected areas system (World Bank, 2011).

Our conclusion that deforestation is unlikely to decrease below the 1990-2005 level is also supported by more recent empirical evidence that points towards an increasing deforestation rate. As the main cause of deforestation is slash-and-burn agriculture, the frequency of fire is a reliable indicator of deforestation. The Fire Alerts System (<https://firealerts.conservation.org/>) uses MODIS to monitor fire occurrence in Madagascar and provides a reliable record of the location and occurrence of fire. The frequency of fire shows a reliable correlation ($R^2 = 0.6125$) with deforestation within each of the administrative regions monitored by the Fire Alerts System (see Table 10 and 17). The occurrence of fire also increased between 2002 and 2010 (see Table 11 and Figure 18).

Table 10. Deforestation and fire frequency for the administrative districts of Madagascar

Region	Deforestation 00 - 05 Ha/yr	Frequency 02 - 05 Number/yr
ALAOTRA MANGORO	1,602	350
AMORON I MANIA	599	112
ANALAMANGA	18	0
ANALANJIROFO	39	160
ANOSY	1,492	197
ATSIMO ATSIANANA	945	272
ATSIANANA	1,682	272
HAUTE MATSIATRA	42	61
IHOROMBE	315	168
VAKINANKARATRA	484	28
VATOVAVY FITOVINANY	366	155

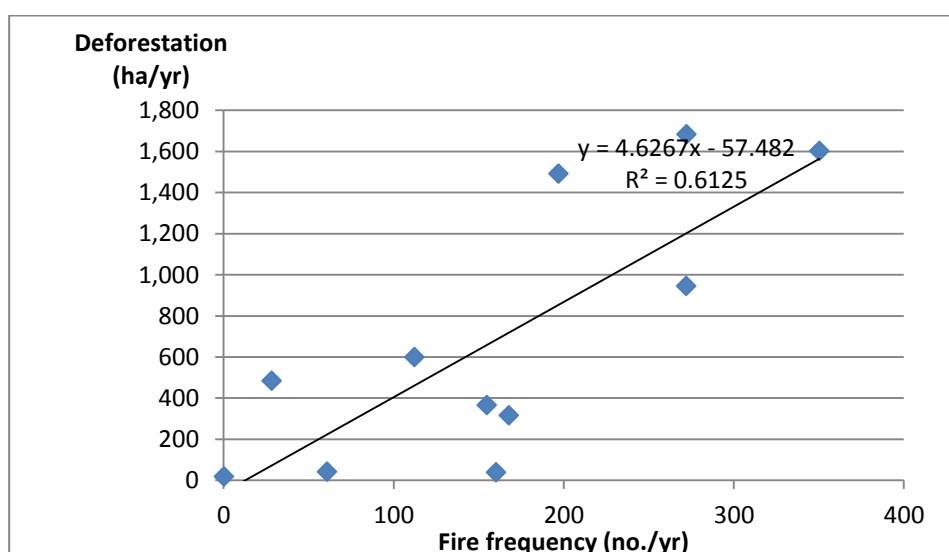
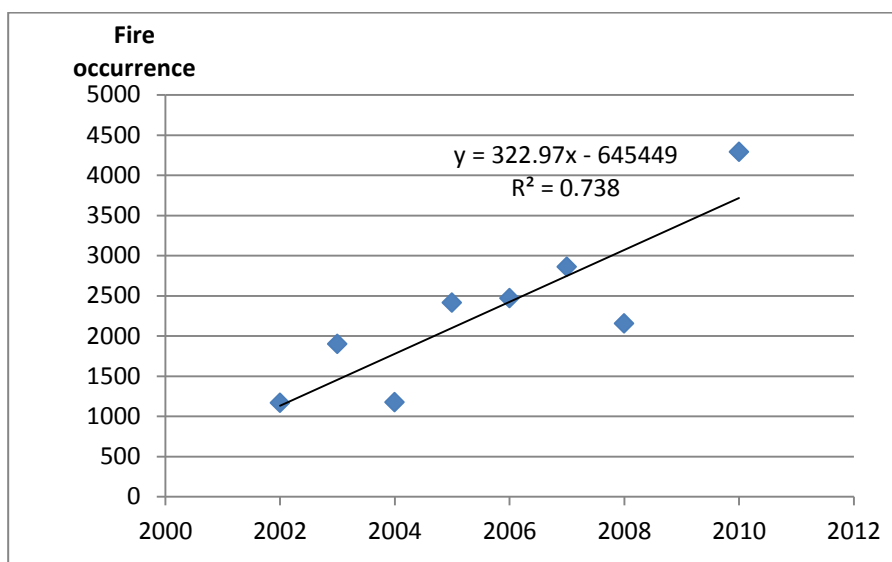


Figure 17. Correlation between deforestation and fire frequency for Madagascar

Table 11. Annual occurrence of fire within Madagascar between 2002 and 2010

Year	Fire occurrence
2002	1167
2003	1898
2004	1174
2005	2414
2006	2470
2007	2859
2008	2152
2010	4290

**Figure 18. Annual occurrence of fire within Madagascar between 2002 and 2010**

As shown later in this section, the map of suitability for future deforestation indicates ample forest land remaining in the site, enough to absorb the proposed baseline deforestation rate over 10 years. Most importantly, the continued level of political will and financial investment in sustainable development and conservation has not been sustained. As noted in the sections 3.1, 3.2 and 3.3, the underlying pressures leading to deforestation are likely to increase rather than decrease. Baseline deforestation therefore is likely to increase over that for the period 1990-2005 or, at the very least, remain at a constant level. We conservatively conclude that the overall trend in future baseline deforestation rates will remain constant at the average rate that has been observed over the 1990-2005 period.

2.5 Additionality

As required by the methodology, the project uses the most recent version (3.0) of the VCS Tool VT0001 “Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities” in order to demonstrate the additionality of the CAZ project. The project meets the applicability conditions of this tool since:

- a) The AFOLU project activities do not lead to the violation of any applicable law (see PD section 1.10);
- b) The baseline methodology used for this project (VM0015) provides for a stepwise approach justifying the determination of the most plausible baseline scenario.

The steps of the tool have been applied as follows:

Step 1. Identification of alternative land use scenarios to the proposed VCS AFOLU project activity

This step serves to identify alternative land use scenarios to the proposed REDD project activity that could be the baseline scenario, through the following sub-steps:

Sub-step 1a. Identify credible alternative land use scenarios to the proposed VCS AFOLU project activity:

Based on current existing land uses or those that have existed at some time ten years prior to the project start date and taking into account relevant national and/or sectoral policies, the following realistic and credible alternative land use scenarios have been identified that could have occurred on the land within the project boundary in the absence of the REDD project activity:

i) Continuation of the pre-project land use:

Continued deforestation and conversion of forest to other land uses due to Tavy (slash-and-burn agriculture), in combination with a number of other less intensive practices (namely subsistence harvesting of timber and non-timber forest products, small-scale logging and mining). Details of the pre-project land use are given in section VM Step 3: Analysis of agents, drivers and underlying causes of deforestation.

ii) The proposed AUD project activity on the land within the project boundary without being registered as a VCS AFOLU project, i.e. in the absence of carbon financing from REDD.

This scenario must be included according to the methodology but it is not credible since any forest protection activities would need long term funding. Even the existing network of national parks and reserves does not have sufficient financial resources to operate effectively and long term funding is not secured (MacKinnon et al., 2009; World Bank 2010). Additional protection of forests in Madagascar for areas such as CAZ is inconceivable based on historical levels of traditional funding sources from international donors and government.

Sub-step 1b. Consistency of credible land use scenarios with enforced mandatory applicable laws and regulations

The following alternative land use scenarios listed in Sub-step 1.a are permitted in Madagascar and could be practised in the corridor:

- Project activity on the land within the project boundary performed without being registered as the VCS AFOLU project

The following activities are carried out in such a way that they do not meet the relevant regulations and would not be permitted in their current form if the relevant laws and regulations were properly enforced:

- The pre-project land-use dominated by *Tavy* (specifically *tevia* – the clearing of forest for agriculture)

However, the current, widespread practice of these activities in the region and throughout Madagascar shows that the laws and regulations governing them are systematically not enforced and that non-compliance is widespread (ANGAP 2001; MINENVEFT et al., 2009; MEF, 2010).

In practice, the capacity of the Forest Administration to regulate access is limited and is essentially restricted to the issue of permits at the regional level to commercial loggers and at the local level to agricultural or subsistence users in the case of forests where the administration is present nearby. Permits are typically issued without any systematic field verification or monitoring for compliance (USAID, 2005; Global Witness & Environmental Investigation Agency, 2010). In remote areas where forest is plentiful and state authorities absent (such as the zones where *Tavy* is heavily practiced) access may be essentially free and open. In more densely populated areas where resources are in shorter supply, there is typically some form of local regulation that affects access linked to customary tenure rights or locally declared taboos. Where the state is present, it may operate against the local interest, such as awarding permits to commercial loggers or migrants to clear forest for agriculture. There is a systematic lack of enforcement of forestry laws and regulations throughout the country and official permits reportedly account for less than 5% of the forest products consumed in Madagascar (USAID, 2005).

Outcome of sub-step 1.b: Since the applicable mandatory legal or regulatory requirements are systematically not enforced and non-compliance is widespread all of the scenarios listed in sub-step 1.a are plausible alternative land uses to the proposed project activity.

Sub-step 1c. Selection of the baseline scenario:

Scenario 1, or continued unplanned deforestation and conversion of forest to other land uses due to *Tavy* (slash and burn agriculture), represents the most plausible alternative land use scenario in the absence of the REDD project as it is the most widespread land use throughout the reference region and project area, despite not being in compliance with the national legislation. The baseline scenario was determined by following the steps outlined in the VCS REDD methodology for Avoided Unplanned Deforestation VM0015, including an in depth analysis of the agents, drivers, and underlying causes of deforestation in the project area. The Barriers Analysis in Step 3 of the Additionality Tool provides further detail on the combination of factors that make the other alternative baseline scenarios unlikely to occur.

Step 2. Investment analysis

The CAZ project is not set up as an economic investment activity. In the absence of carbon finance from the sale of GHG credits, the Project Proponent would not be able to financially support the scope of activities required to reduce deforestation in the project area.

Sub-step 2a. Determine appropriate analysis method

The proposed AUD project activity will generate no financial benefits for the Project Proponent other than carbon market-related income. It involves preventing deforestation through the establishment of a protected area, an activity that will not generate other direct incomes. Therefore a simple cost analysis is applied.

Sub-step 2b. Option I: Simple cost analysis

The costs of establishment and management of the protected area and the leakage prevention activities are detailed in the CAZ financial plan, which is available to the validator on request (see Financial Viability analysis in the Non-Permanence Risk Assessment). Income for the project activity will be generated solely through the sale of VCU and the proposed AUD project activity produces no financial benefits other than carbon market-related income.

Step 3: Barrier analysis

As an extension to the simple cost analysis carried out in Step 2, a barrier analysis is performed to further illustrate the additionality of the project.

Sub-step 3a. Identify barriers that would prevent the implementation of the type of proposed project activity

The proposed project activity is founded on the creation and long-term, effective running of a large-scale protected area and its associated development and conservation activities with the neighbouring communities. The principal barriers that would prevent the implementation of the type of proposed project activity from being carried out if the project activity was not registered as a VCS AFOLU project include:

Investment barriers

Long term funding is not available for this type of project activity:

The scale of this activity to reduce deforestation is unprecedented for non VCS AFOLU projects in Madagascar. The history of domestic government investment in nature conservation shows that the funding necessary would not come from government sources (MacKinnon et al, 2009). Similarly, no such investments on this scale have been made through donor support. No donors have made commitments to fund long term conservation work in Madagascar (MacKinnon et al, 2009). Some donors have provided funding to a national Protected Area and Biodiversity Trust Fund but contributes only a small proportion of the costs of existing protected areas (Fondation pour les Aires Protégées et la Biodiversité de Madagascar, 2010) and is not expected to contribute to CAZ. As of 2012 there are no significant donor programs for the environment with the exception of a credit taken by the Government of Madagascar from the World Bank to maintain part of the protected area

system and to finance the investment phase of 3 proposed VCS AFOLU projects before they generate revenues from VCUs.

Institutional barriers

Lack of enforcement of forest or land-use-related legislation:

Generally widespread non-compliance with land-use and forest management regulations mean that the long term protection of natural forest would not be assured by law, nor is the reality of land-use conducive to forest protection over the project lifetime.

Long experience has shown that laws governing forest are largely ineffective in Madagascar and that Madagascar's forests have decreased throughout most of the twentieth century (Moser 2008, USAID, 2010). Root causes for continued deforestation on a national level include: the linking of forest clearing to land ownership; reduced public expenditure has diminished the government means to enforce and monitor of existing environmental legislation; regulations that make no accommodation for traditional livelihoods and therefore are not respected by local communities; and national level policies that are neither coordinated nor complementary and a lack of formal land tenure (MINEVEFT et al. 2009, Moser, 2008; RPP, 2010).

Barriers relating to local tradition

The *Tavy* slash-and-burn system is deeply rooted in traditional agricultural practice in Madagascar and its widespread use is likely to persist (Styger et al., 2007; Styger et al., 2009). Traditional customs present a barrier to the land use change practices necessary to implementing the project activities on the lands that traditional farmers would use in the absence of the project activity.

Barriers relating to land tenure, ownership, inheritance and property rights:

The current land tenure regime in rural areas poses another institutional barrier to the long-term protection of the corridor (Aubert et al., 2003; Messerli, 2004). Within the region of the project area, there has historically been a *de facto* occupation of state-owned forest land by *Tavy* farmers, coupled with very few individual farmers gaining legal title to their cropland (PGEES, 2012). In addition, both the traditional and official land tenure systems recognise a farmer's right to land if they have cleared the forest and worked the parcel for seven years. These factors combine to encourage the continued practice of *Tavy*.

Sub-step 3b. Show that the identified barriers would not prevent the implementation of at least one of the alternative land use scenarios (except the proposed project activity):

These barriers would prevent the implementation of scenario 2, the implementation of the project activity within the project boundary without being registered as a VCS AFOLU project.

By contrast these barriers would all maintain the pre-project situation of continued deforestation and conversion of forest to other land uses due to *Tavy* (slash-and-burn agriculture).

Step 4. Common practice analysis

In Madagascar is not a common practice to implement conservation projects through carbon finance. Except a single REDD project being implemented in the region, there is no record of any project in the region that has performed similar activities that compare to the scale and timeframe of those proposed by CAZ. The proposed REDD project aims to implement a unique strategy of combating deforestation in CAZ through a co-managed protected area in which local community groups are an essential actor in the governance structure. Although there are other forest protected areas in the region (see Table 18), these have fundamental differences in that they are much smaller scale, they are mostly run by the government's Madagascar National Parks service, and they have fundamentally different funding strategies and future prospects. The established protected areas managed by Madagascar National Parks are Mangerivola, Betampona, Analamazaotra-Mantadia and Zahamena.

As part of the national network of protected areas and managed by Madagascar National Parks, the government provides for the essential budget of these sites through a combination of grants and loans from donors and government appropriations. The Analamazaotra and Mantadia protected areas also have an important tourism objective and generate revenues that helps to sustain them and contribute to the funding of other protected areas in the national network (ANGAP, 2001). By contrast, there is no long term government commitment to fund activities at CAZ and most of the funds for the start up phase have been raised by Conservation International from a variety of sources with the objective of ensuring that carbon revenues cover the long term costs.

Table 18. Existing conservation activities in the vicinity of the project area

Name of protected area	Status(a)	Approximate surface area (ha)	Principal vegetation	Date proclaimed
Mantadia	PN ^(a)	10,000	dense humid evergreen forest	January 1989
Analamazaotra	RS	800	dense humid evergreen forest	July 1970
Mangerivola	RS	11,900	dense humid evergreen forest	October 1958
Zahamena	PN	41,400	dense humid evergreen forest	August 1997
	RNI	22,500	dense humid evergreen forest	December 1927

(a) PN: Parc National; RNI: Reserve Naturelle Integrale; RS: Reserve Speciale.

(b) Proposed or has a designation offering limited protection.

The CAZ project is one of the first of its kind within Madagascar and was conceived in the early 2000's as a pilot project to demonstrate the use of carbon finance for the large-scale protection of a corridor and the development of the surrounding rural communities. Prior to CAZ, no other project had undertaken such a diverse range of forest protection and development activities on the same scale.

In conclusion, the proposed CAZ project is considered additional since it is fundamentally different from the baseline scenario and no other credible similar activities could be done in the project area at the scale of the CAZ project.

2.6 Methodology Deviations

The historical land cover and land use change analysis, which was also used to estimate the baseline, was performed based on a national mapping effort by the Malagasy government (Jariala, 2009). The forest cover and loss was classified using mid-resolution (30 m) Landsat imagery. The final product classification was filtered to a Minimum Mapping Unit (MMU) of 2 hectares, eliminating small patches of forest and forest loss, and improving the overall classification accuracy. This is in compliance with version 1.0 of the methodology, which requires the MMU to be *equal or at most 5 times above the minimum area threshold used for defining "forest"*.

Version 1.1 of the methodology, approved on December 03, 2012, changed the MMU requirement to a minimum of 1 hectare, irrespective of forest definition. Even though the MMU used by the project does not currently meet the new requirement, it is likely to be more conservative than the 1 ha MMU suggested by the methodology, as changes below 2 ha will not be counted as deforestation in the baseline.

3 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

3.1 Baseline Emissions

VM Step 4: Projection of future deforestation

VM 4.1 Projection of the quantity of future deforestation

The VM0015 methodology suggests, if appropriate, stratifying the reference region according to the results from the analysis of agents and drivers of deforestation (Step 3). In the case of CAZ, Tavy is the single cause of significant deforestation in the reference region. The agents, drivers and underlying causes of deforestation by Tavy described in the previous step are homogeneously distributed in the reference region. (forest areas having distinct patterns of deforestation from this were excluded from the reference region in keeping with the criteria defined in step 1.1.1 of VM0015.). It is unlikely that future developments will change these causes of deforestation; therefore the reference region is not divided into different strata (VM Table 8).

VM Table 8. Stratification of the reference region

Stratum ID <i>ID_i</i>	Stratum ID	Description	Area ha
	Name		
1	Reference region	The causes of deforestation are homogeneously distributed in the reference region, therefore there is no need to be subdivided in different strata.	4,966,685*

* 1,006,426 hectares of the reference region is forest at the project start date

VM 4.1.1 Selection of the baseline approach

The conclusion of the historical deforestation analysis in combination with the analysis of drivers and agents of deforestation was a constant trend of deforestation. Therefore approach “a” the historical average approach is used here.

VM 4.1.2 Quantitative projection of future deforestation

We apply the historical average rate of 1.26% deforestation per year to the entire reference area over the project timeline (approach “a”), with distinct time steps for each 5-year reporting period.

VM 4.1.2.1 Projection of the annual areas of baseline deforestation in the reference region

The annual baseline deforestation area that applies at year t to stratum i within the reference region is calculated using approach “a”: Historical average as follows:

$$ABSLRR_{i,t} = ARR_{i,t-1} * RBSLRR_{i,t}$$

Where:

$ABSLRR_{i,t}$ Annual area of baseline deforestation in stratum i within the reference region at year t ; ha yr⁻¹

$ARR_{i,t-1}$ Area with forest cover in stratum i within the reference region at year $t-1$; ha

$RBSLRR_{i,t}$ Deforestation rate applicable to stratum i within the reference region at year t ; %

t 1, 2, 3 ... T , a year of the proposed crediting period; dimensionless

i 1, 2, 3 ... I_{RR} , a stratum within the reference region; dimensionless

VM 4.1.2.2 Projection of the annual areas of baseline deforestation in the project area and leakage belt

The portion of the annual areas of baseline deforestation for each forest class within the project area and leakage belt was determined using GIS. The map of forest classes was overlaid with the projected yearly deforestation maps developed in step 4.2.4.

VM 4.1.2.3 Summary of step 4.1.3

The results of this step are presented in VM Table 9a, 9b and 9c.

VM Table 9a. Annual areas of baseline deforestation in the reference region

Project year	Stratum i in the reference region $ABSLRR_{i,t}$ ha	Total	
		annual	cumulative
		$ABSLRR_t$ ha	$ABSLRR$ ha
2008	12,363	12,363	12,363
2009	12,208	12,208	24,571

2010	12,054	12,054	36,625
2011	11,902	11,902	48,527
2012	11,752	11,752	60,279
2013	11,604	11,604	71,883
2014	11,458	11,458	83,340
2015	11,313	11,313	94,654
2016	11,171	11,171	105,824
2017	11,030	11,030	116,855

VM Table 9b. Annual areas of baseline deforestation in the project area

Project year	Stratum <i>i</i> of the reference region in the project area		Total	
	For Cat A $ABSLPA_{i,t}$ ha	For Cat B $ABSLPA_{i,t}$ ha	annual $ABSLPA_t$ ha	cumulative $ABSLPA$ ha
2008	542	2,089	2,632	2,632
2009	792	2,908	3,699	6,331
2010	1,030	3,644	4,675	11,006
2011	1,503	3,790	5,293	16,299
2012	1,899	3,519	5,418	21,717
2013	2,153	3,616	5,769	27,486
2014	2,352	2,773	5,125	32,612
2015	1,867	2,353	4,220	36,832
2016	1,799	2,269	4,068	40,900
2017	1,914	2,076	3,990	44,890

VM Table 9c. Annual areas of baseline deforestation in the leakage belt

Project year	Stratum <i>i</i> of the reference region in the leakage belt	Total	
	1 $ABSLK_{i,t}$ ha	annual $ABSLK_t$ ha	cumulative $ABSLK$ ha
2008	4,707	4,707	4,707
2009	4,014	4,014	8,722
2010	2,902	2,902	11,624
2011	2,837	2,837	14,461
2012	2,623	2,623	17,083
2013	2,028	2,028	19,111
2014	1,963	1,963	21,075
2015	1,872	1,872	22,947

2016	1,982	1,982	24,929
2017	1,854	1,854	26,783

VM 4.2 Projection of the location of future deforestation

To predict future deforestation, we developed and tested a model using IDRISI Land Change Modeller (LCM), chosen because of its non-reliance on independence among driver variables, as it is based on a neural network rather than on multiple regressions. After defining the total deforestation baseline for the modelled period, we prepared spatial data on driver variables, produced a map of locations' "potential" for deforestation (or "transition potential", "risk" or "suitability" for deforestation - different authors use different terms for the same concept), and produced a map of projected locations of future deforestation.

LCM uses a neural network approach for modelling the "risk" map. Neural network is a multilayer perceptron in which a first set of known areas of change (historical deforestation) are used as training areas to develop a relationship with factor maps using an activation function. Once the development of the relationship is complete a second set of known areas of change is used to test the relationship and confirm the activation level maps.

For the geographical analysis, the model calibration was done using data on deforestation from 1990 to 2000, and the model was confirmed/ validated using data on deforestation from 2000 to 2005. The distribution of deforestation events during the calibration period was compared to the suite of driver variables, and a deforestation model was created using the neural network algorithm/ engine. Following this, the resulting model was used to produce a deforestation risk map, scaled from 0 to 1.

VM 4.2.1 Preparation of factor maps

In this analysis, we applied **heuristic approach** to create the factor maps. More specifically distance maps were generated using Euclidean distances and slope and elevation were used as continuous variables. Factor map for discrete data, like protected areas and administrative units, was generated by evidence likelihood variables. The evidence likelihood variables estimate the probability of deforestation in each unit (polygon) based in the historical deforestation and uses an index of deforestation.

VM0015 suggests that *empirical* approach be preferred over *heuristic* if there is sufficient information about the location of the of historical deforestation, however distance maps categorized by classes (e.g. class 1 distance between 50 and 150, class 2 distance between 151 and 250...) are not the ideal input variables in the LCM. Categorizing variables also requires assumptions and sometime guesswork to create classes, making the variable very subjective. LCM automatically created classes (virtual nodes) based on the spatial correlation between the factor maps and the historical deforestation data.

As noted in VM Step 3, the categories of drivers identified for this area are the rural population that is dependent on farming, access to the forest, and terrain. We applied the following geographic data, available in digital format, to represent these drivers:

Population:

- Commune and fokontany locations. Rather than use population size, we used these spatial units as a driver variable, using the evidence likelihood routine within LCM. This calculates rates of historical deforestation among the units and provides a map of the likelihood of deforestation based on these polygons and their associated rates alone. While this does not strictly apply these rates to the future projections, it uses the evidence likelihood map as one of the inputs to the neural network, just as any of the other driver variables.

Access to forest:

- Distance to roads. Roads were separated into tarred, untarred and cart tracks. A linear distance map was created for each road type.
- Distance to rivers. A linear distance map was created for distance to the nearest river.
- Protected forest areas. Areas of forest under current protection are assumed to be of low accessibility for deforestation because they are guarded. This is also evidenced in the very low deforestation rates ($<0.1\% \text{ y}^{-1}$) inside them during the historical reference period. Polygons for the protected areas were used to create evidence-likelihood maps for protected versus unprotected areas, using the same routine that was used to create the evidence-likelihood layer for the population districts.

Terrain:

- Elevation. Obtained from the Shuttle RADAR Topography Missions (SRTM) of NASA, with a 90-meter horizontal resolution and 10-meter vertical resolution.

Other correlated variables (e.g. population that is correlated with town distribution) were not considered in the analysis.

VM 4.2.2 Preparation of risk maps for deforestation

Various combinations of the above driver variables and the deforestation between 1990 and 2005 were used to produce maps of deforestation risk. These maps were produced for every pixel in the reference region.

The resulting map of deforestation risk was then used to predict the deforestation location in the confirmation period 2000 - 2005. The actual deforestation rate for 2000 - 2005 was entered, therefore only the model's performance to predict the location was assessed. On the following pages the factor maps used in the final model and the plotted relationship between each driver variable and deforestation are shown. The maps show the driver's spatial variation within the reference region.

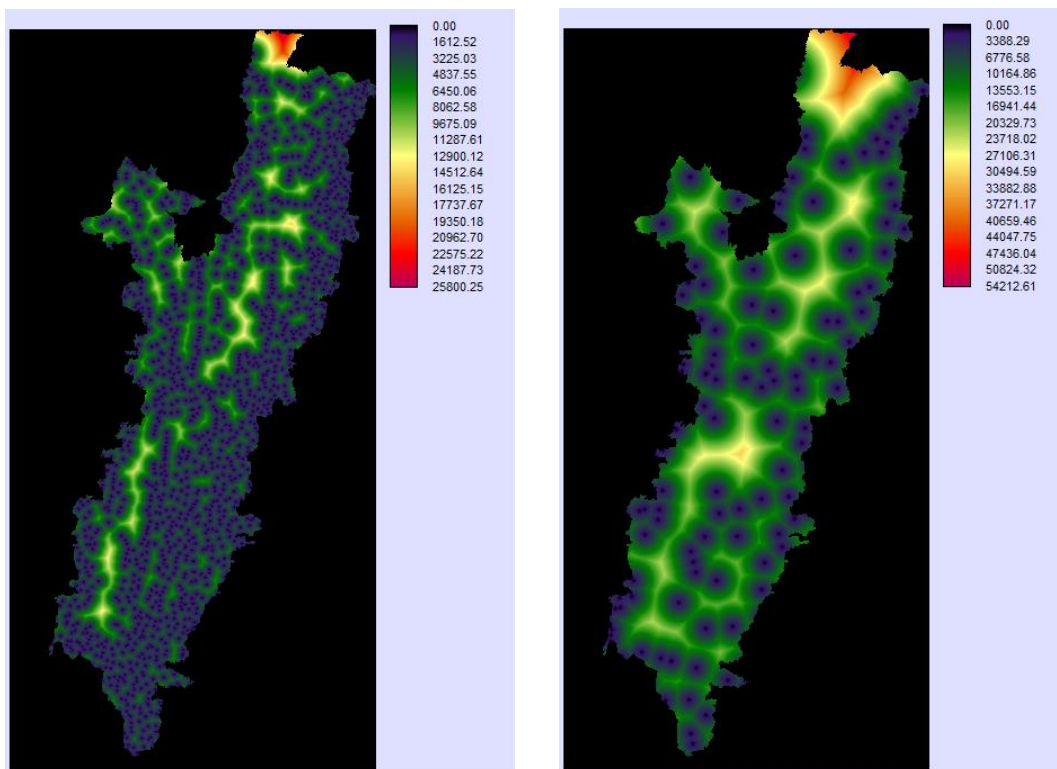
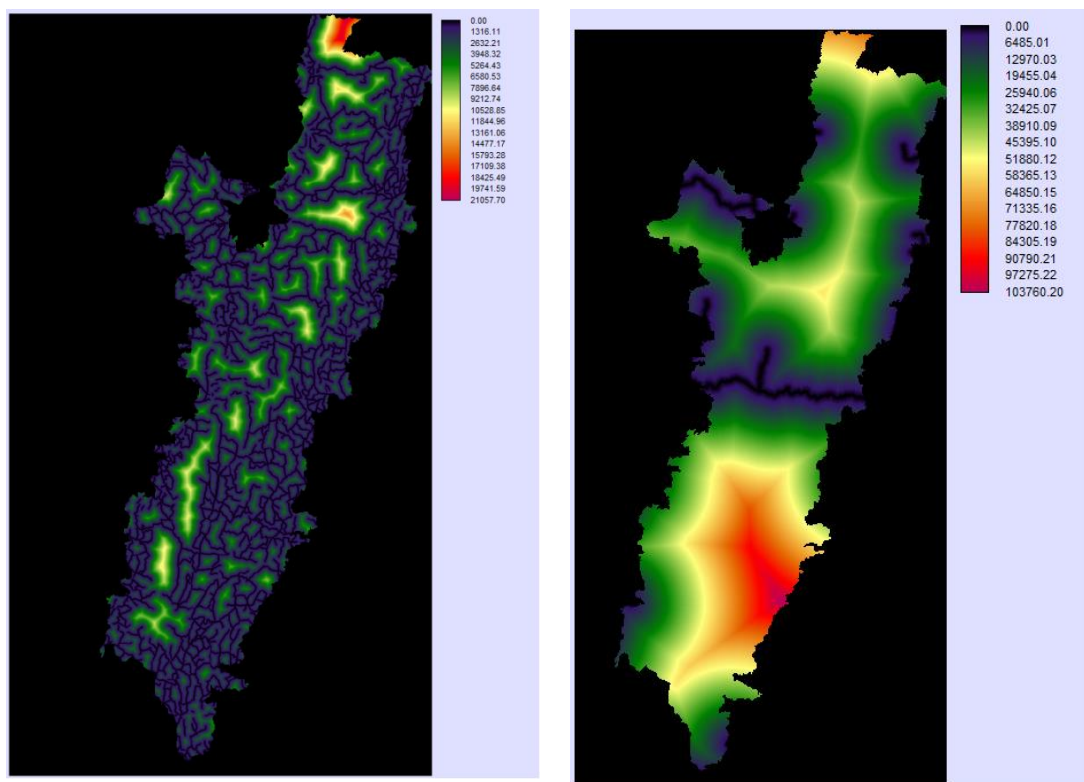


Figure 19a. Factor maps for population centres. The maps represent the distances from the Fokontany (left) and Commune (right)



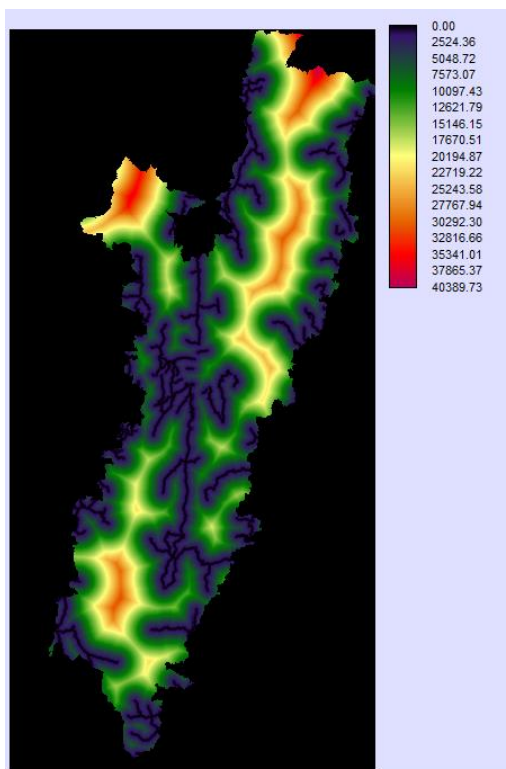


Figure 19b. Proximity to roads within the reference region. The map shows distance to paths, secondary tracks and surfaced roads (units: meters)

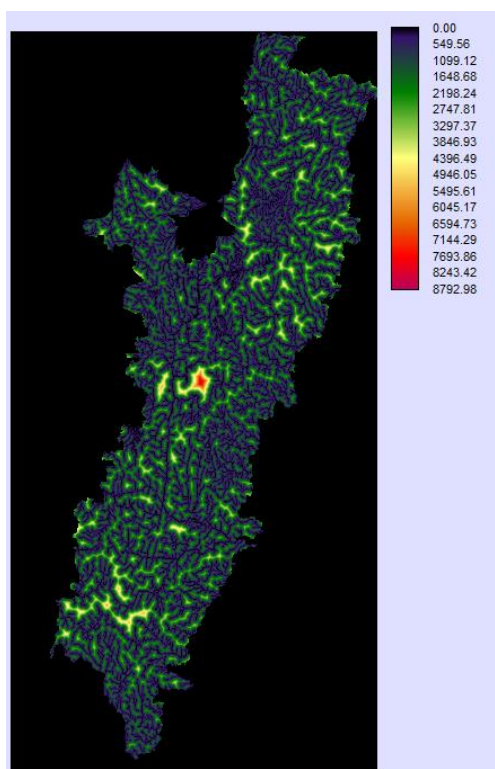


Figure 19c. Proximity to rivers. The map shows the distance from rivers (units: meters)

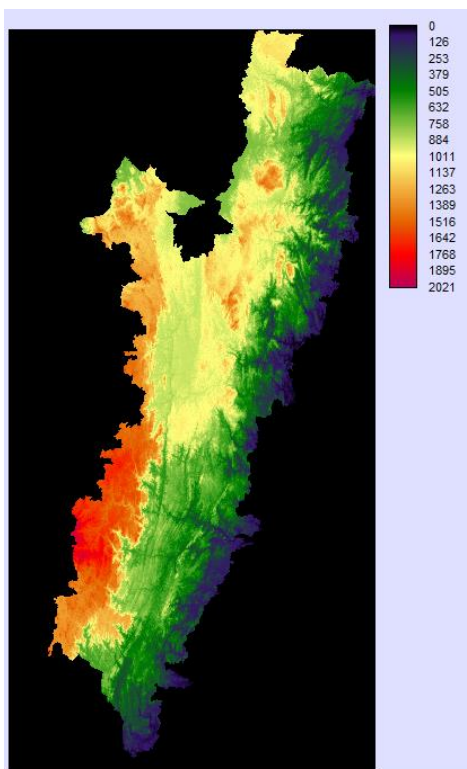


Figure 19d. Elevation. The map shows the distance above sea-level (unit: meters above sea level)

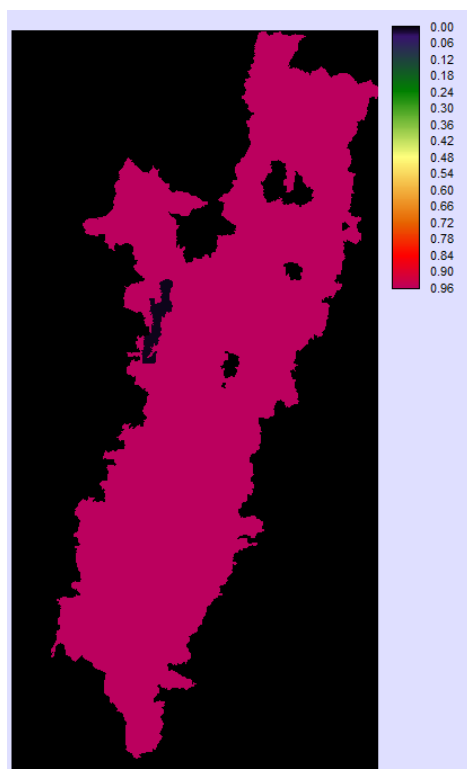


Figure 19e. Evidence likelihood of protected areas (unit: probabilities, dimensionless). The map shows the probability of deforestation within protected areas.

The flowchart below illustrates the process used to model future land cover maps and a list of the factors maps used in the final deforestation risk map (Figure 20).

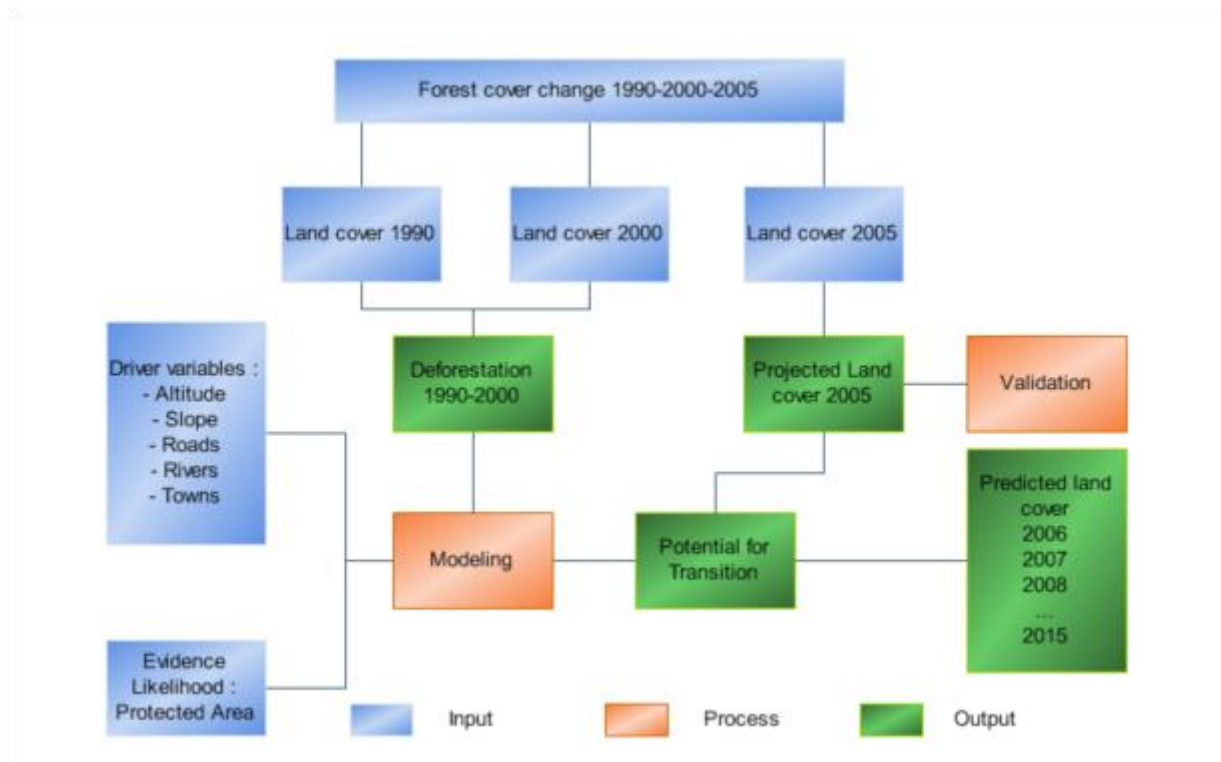


Figure 20. Flow-chart diagram of land cover prediction using IDRISI's LCM tool

VM Table 10. List of variables, maps and Factor Maps

ID	Factor Map File Name	Source	Variable represented		Meaning of the categories or pixel value		Other Maps and Variables used to create the Factor Map		Algorithm or Equation used	Comments
			Unit	Description	Range	Meaning	ID	File Name		
1	aspect.rst	GDEM	Degrees	angular unit from the north of the orientation of a slope	0-360	0 is north		dem2real.rst		
2	dist_for_edge.rst	Forest cover map 1990	meter	distance from the edge of the forest going inside		Euclidian distance		forest1990.rst		dynamic variable since the forest edge is changing constantly due to forest loss
3	dist_railroad.rst*	BD500	meter	distance from railroad		Euclidian distance				
4	dist_river.rst*	BD500	meter	distance from permanent river		Euclidian distance				
5	dist_river_small.rst	BD500	meter	Distance from small seasonal river		Euclidian distance				farmers like to settle not very far from river, also, it has been demonstrated that deforestation most always start by the river where it is transformed into ricefield (IRD document)
6	dist_cart_track.rst*	BD500	meter	distance from non carossable road but accessible via		Euclidian distance				

				cart						
7	dist_road_tared*	BD500	meter	distance from "route national" or main road		Euclidian distance				
8	dist_road_untared*	BD500	meter	distance from secondary untared road		Euclidian distance				
9	dist_region.rst	BD500	meter	distance from regional capital		Euclidian distance				this accounts for access to market and infrastructure
10	dist_district	BD500	meter	distance from district capital		Euclidian distance				
11	dist_commune.rst*	BD500	meter	distance from commune		Euclidian distance				
12	dist_fkt.rst*	BD500	meter	distance from settlement		Euclidian distance				very important as these are the place where all the farmers live
13	altitude.rst*	GDEM	meter	altitude measured from the sea level	300-2000	altitude				
14	slope.rst	GDEM	Degrees	slope	0-90	slope		dem2real.rst		
15	sapm_mnp_evl.rst*	SAPM	probabilities	Empirical likelihood of forest transitioning to non forest inside protected areas network	0-0.05	the lower the value, the less likely to change				this varialbe accounts for the management differences between protected and non protected forest

* Variables with an asterix were included in the final 8 variable model

VM 4.2.3 Selection of the most accurate deforestation risk map

After the risk map of deforestation has been created, the LCM process is used to distribute spatially the total deforestation rate. LCM assigns deforestation sequentially to the pixels of greatest potential. The quality of the model output was confirmed using option (a), in which the predicted deforestation map is evaluated by comparing with a “true” observation using two sub-periods.

Calibration and confirmation of the risk map was done by comparing the predicted deforestation from 2000 to 2005 to that observed. The map of deforestation risk was cropped to the extent of forest observed in 2000 that was also cloud free in 2005. This excludes clouds in either date and forces the deforestation prediction to occur only in areas that could be potentially observed as deforestation in the validation data, i.e. cloud-free in both dates. (On the other hand, for the projection into the project implementation period, the map of deforestation potential is cropped with the forest benchmark map in 2005, as described in VM Step 2.) In IDRISI's LCM, these crops can be applied during the stage of predicting deforestation by creating a mask raster file and identifying it as a constraints layer.

We also provided the spatial model with the actual deforestation rate for this period in order to predict the location of deforestation, because we do not want to confuse error in the rate with error in the distribution. The predicted deforestation for 2000 to 2005 is displayed beside the actual deforestation in Figure Figure 22. The resultant change map (2000 - 2005) was confirmed with the actual change map produced in the step 2.4, by overlapping both maps in GIS.

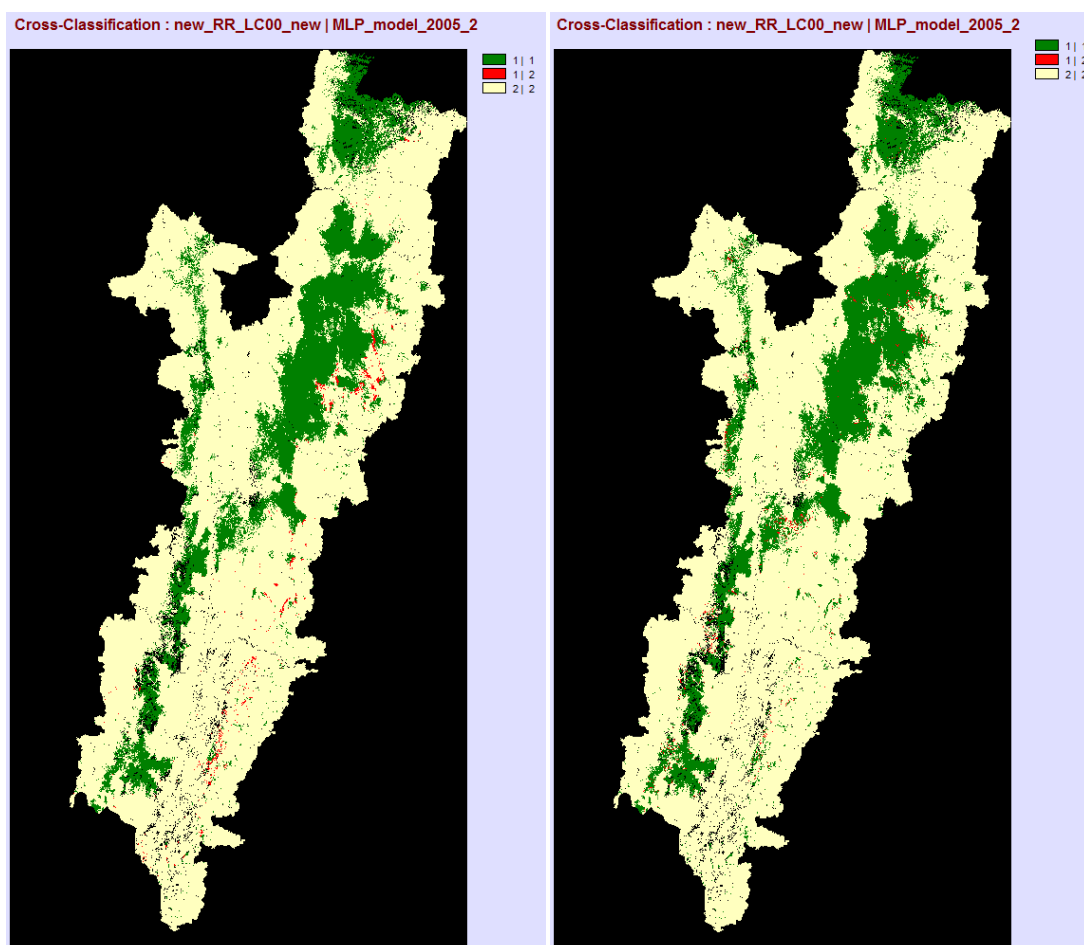


Figure 21. Actual (left) versus predicted (right) deforestation from 2000 to 2005 for the reference area.

The technique assessment - Figure of Merit at polygon level (FOM) - was applied to assess the accuracy of the model in each forest stratum. FOM ranges from 0%, where there is no overlap between observed and predicted change, to 100%, where there is a perfect overlap between observed and predicted change.

Within the project area, the estimated FOM was 4.4% overall. VM0015 requires a minimum threshold for the best fit of equal or superior of the net observed change in the reference region during the calibration period of the model, expressed in percentage. The deforestation in the reference region in the calibration period (1990-2000) was 155,286 ha, which returned a minimum threshold of 3.1%.

Figure 22 is the risk map selected based on the highest FOM. The colors in the map describe the risk of deforestation, with dark red representing high potential, decreasing until low potential represented by dark blue. The left panel shows the parameters used in the model, including start and end leaning rates and final running statistics.

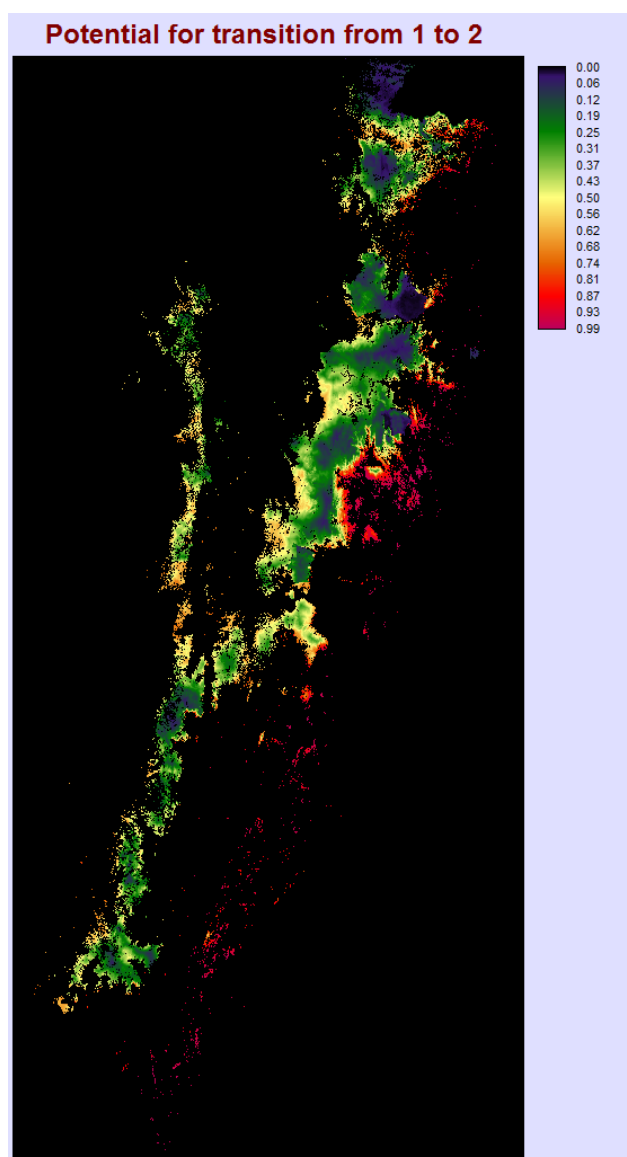


Figure 22. Deforestation risk map for the reference region

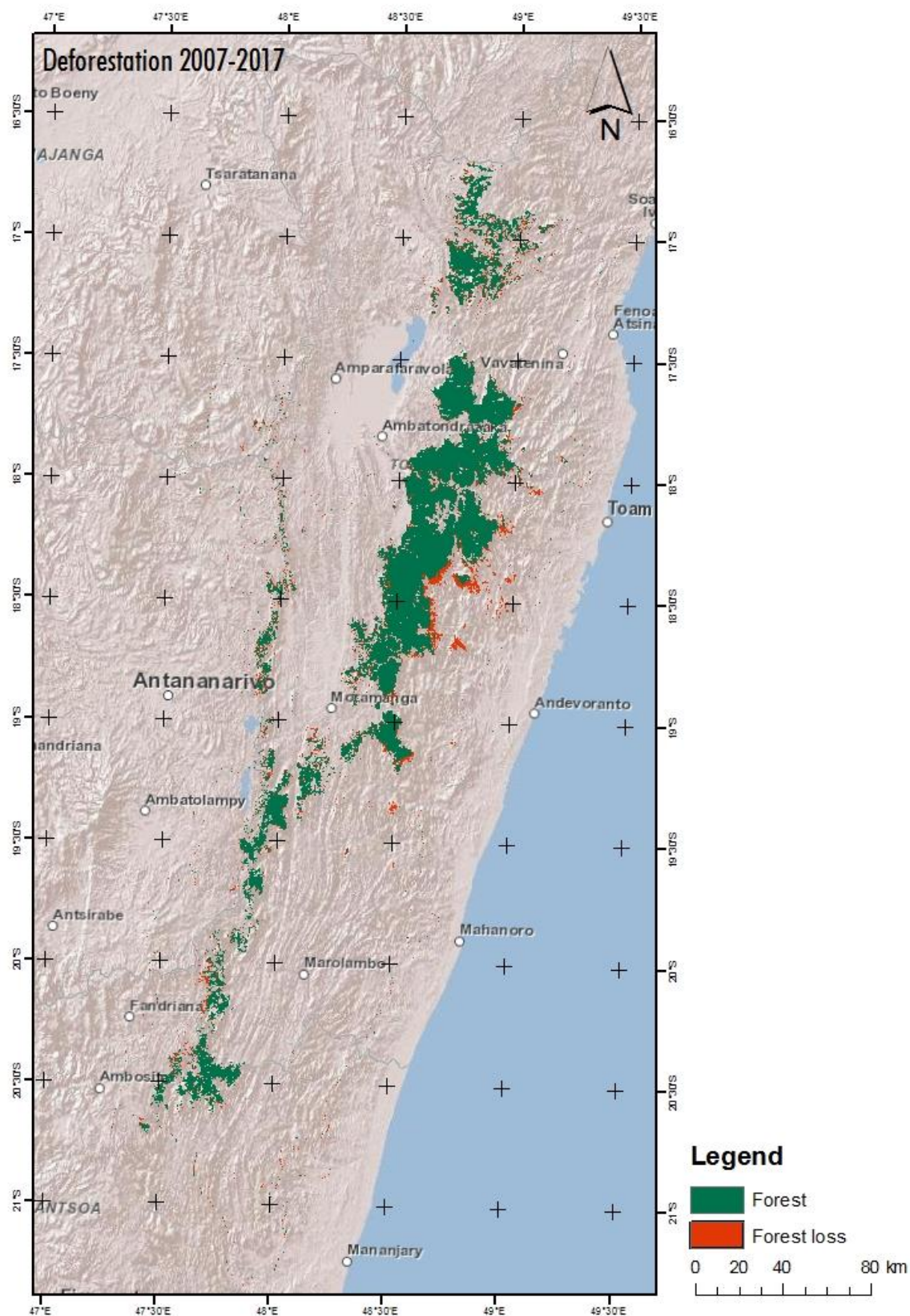
VM 4.2.4 Mapping of the locations of future deforestation

Once the map of deforestation risk has been created, the remaining step in the LCM process is to predict the spatial distribution of deforestation in the reference region given a certain total rate. LCM assigns deforestation sequentially to the pixels of greatest deforestation risk, with a filter function to produce more realistic patches of deforestation (Figures 23a-k).

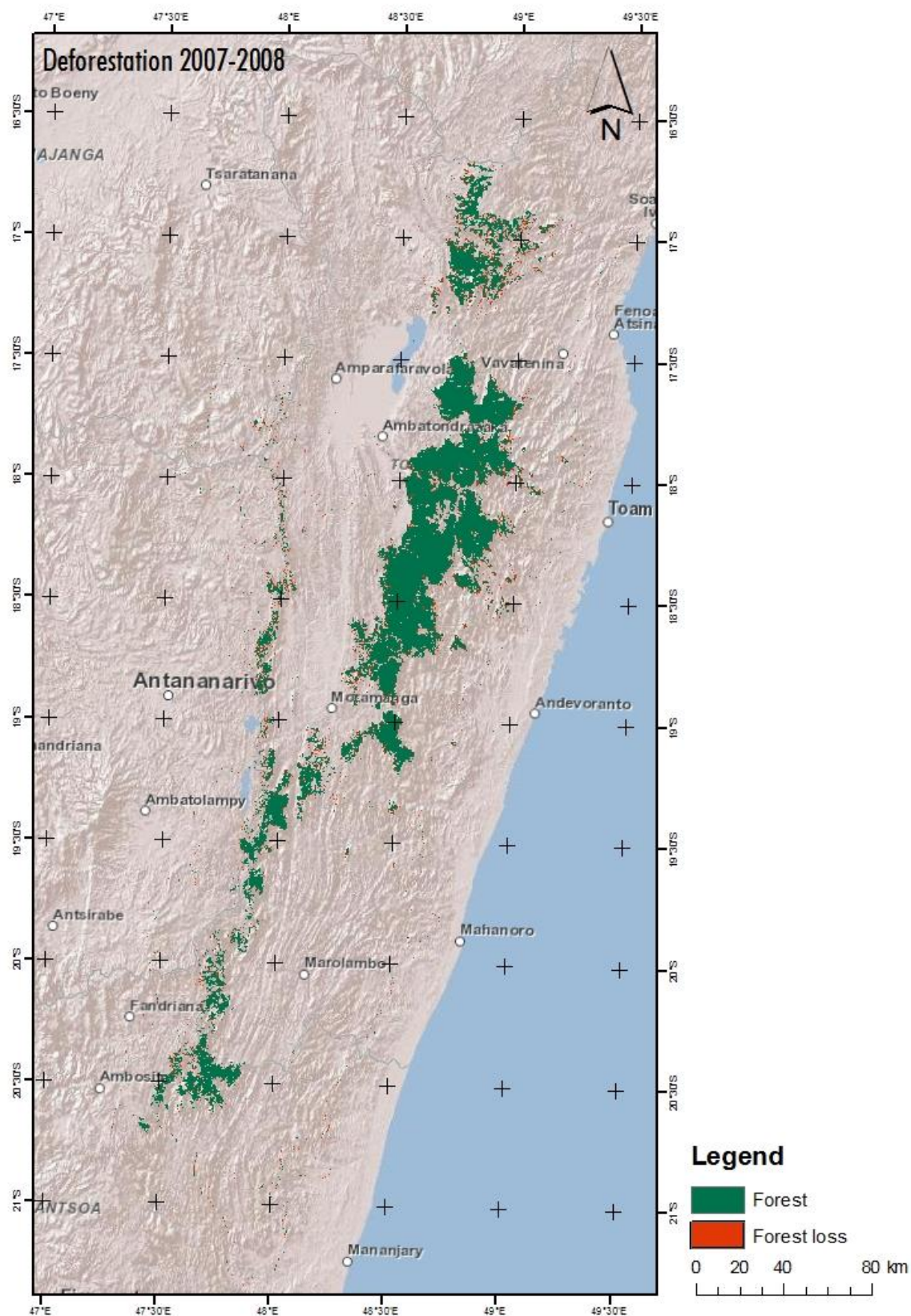
The prediction of deforestation during the project period requires creation of a forest benchmark map for the reference region for the project start date, 2005. The benchmark map used includes all forest observed in 2005. A small remaining portion of the study area, less than two percent, was cloudy in 2005 and therefore were excluded from the project area permanently.

The baseline rate of deforestation that is used for the project implementation period is a conservative assumption based on the historical average rate in the reference area. This rate, estimated in step 4.1.3 and described in VM Table 9.a, was applied to the risk map to determine the location of future baseline deforestation (2008-2017). After the completion of this step, the project area (forest category A and category B) and leakage belt boundaries were overlaid using GIS to estimate the quantity of deforestation that will happen in the baseline scenario within those boundaries. The results are reported in VM Table 9b, and 9c, and VM table 11b, and 11c.

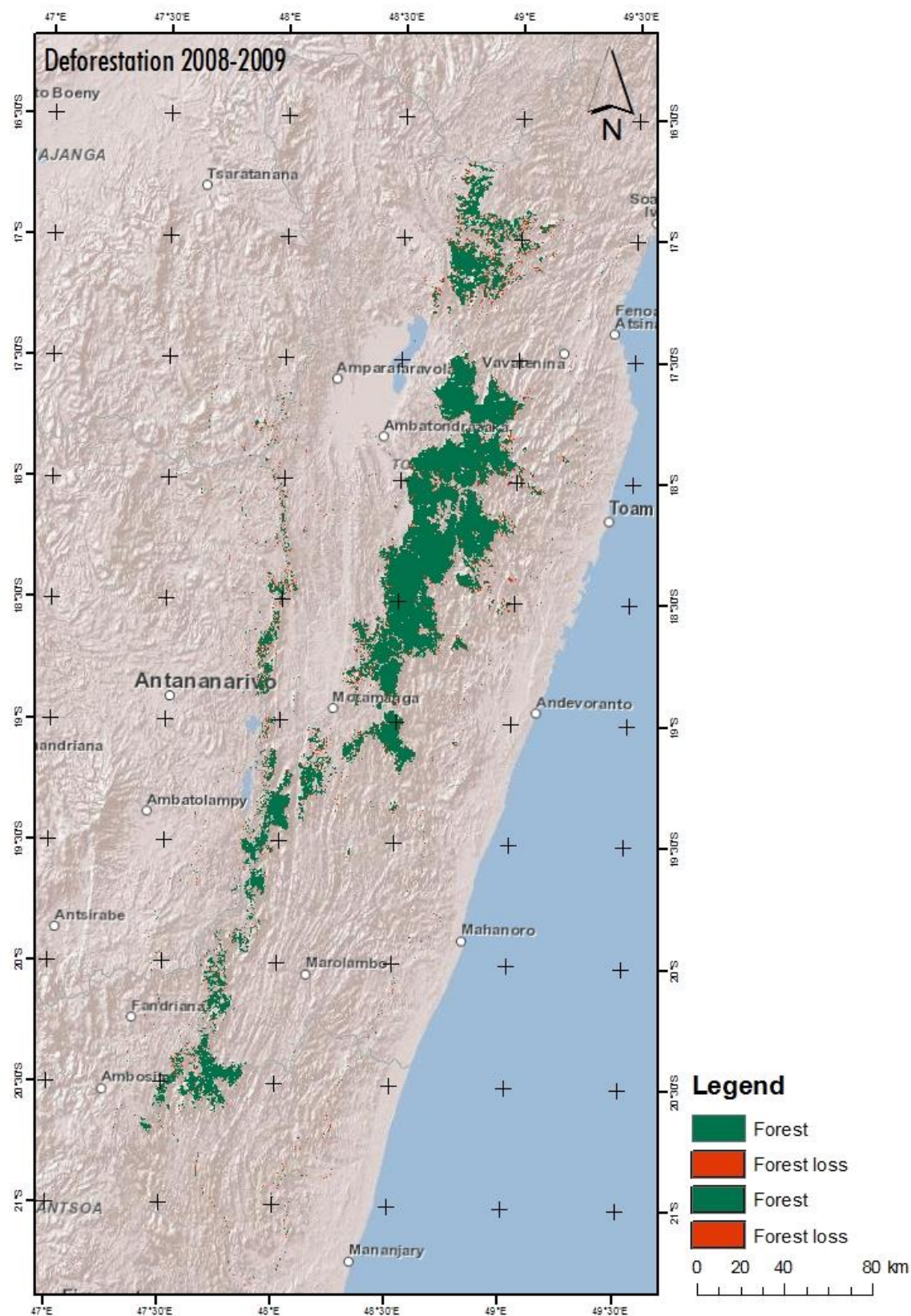
Also excluded from the forest benchmark map for the baseline projection of deforestation are the existing and proposed mining sites, which are a series of 2.5 km by 2.5 km blocks mostly outside of forested areas. These are excluded because the existing and proposed mines will happen with or without the project. Very little deforestation will occur in the mining sites; most of what will occur will be the road network. The project does not include a baseline for the forest in the existing and proposed mining sites. The project however plans to include working with the mining companies on reducing deforestation impacts and possibly in forest restoration. The project reserves the right to include an added baseline for emissions reductions for any such activities at a later baseline period.



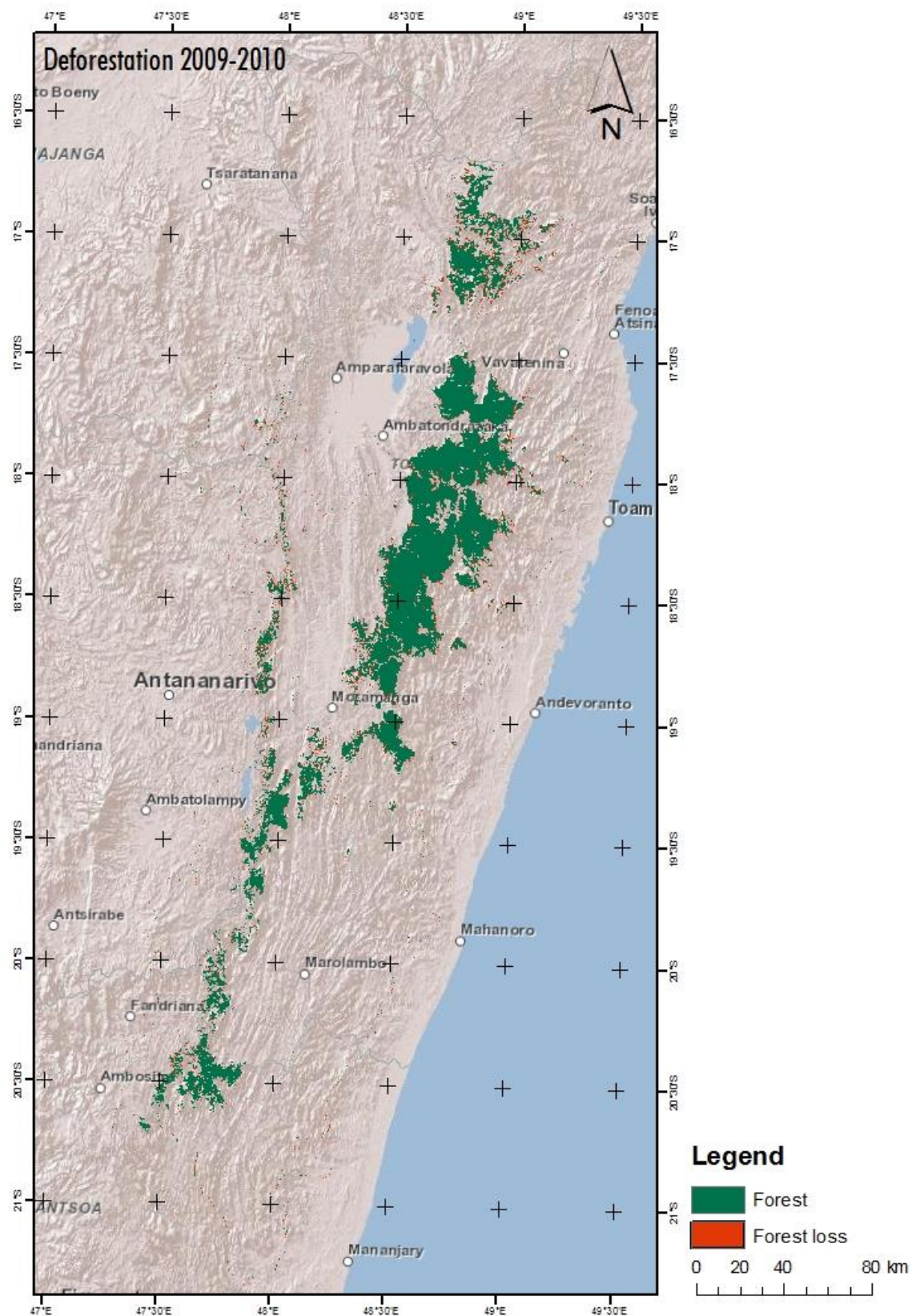
VM Figure 23a. Deforestation in the reference region for the first baseline period (2007-2017)



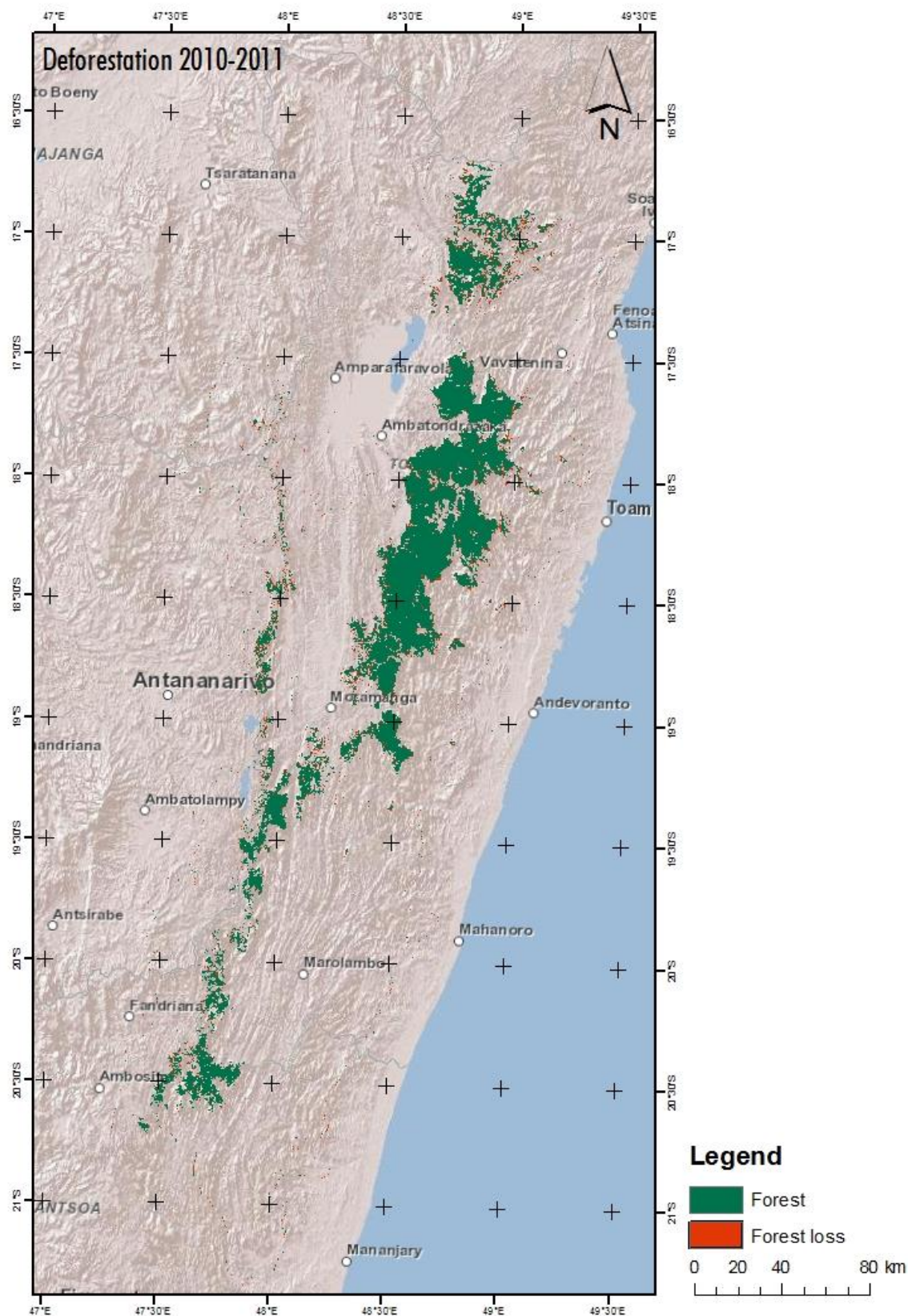
VM Figure 23b. Baseline Deforestation in the reference region for the period 2007-2008



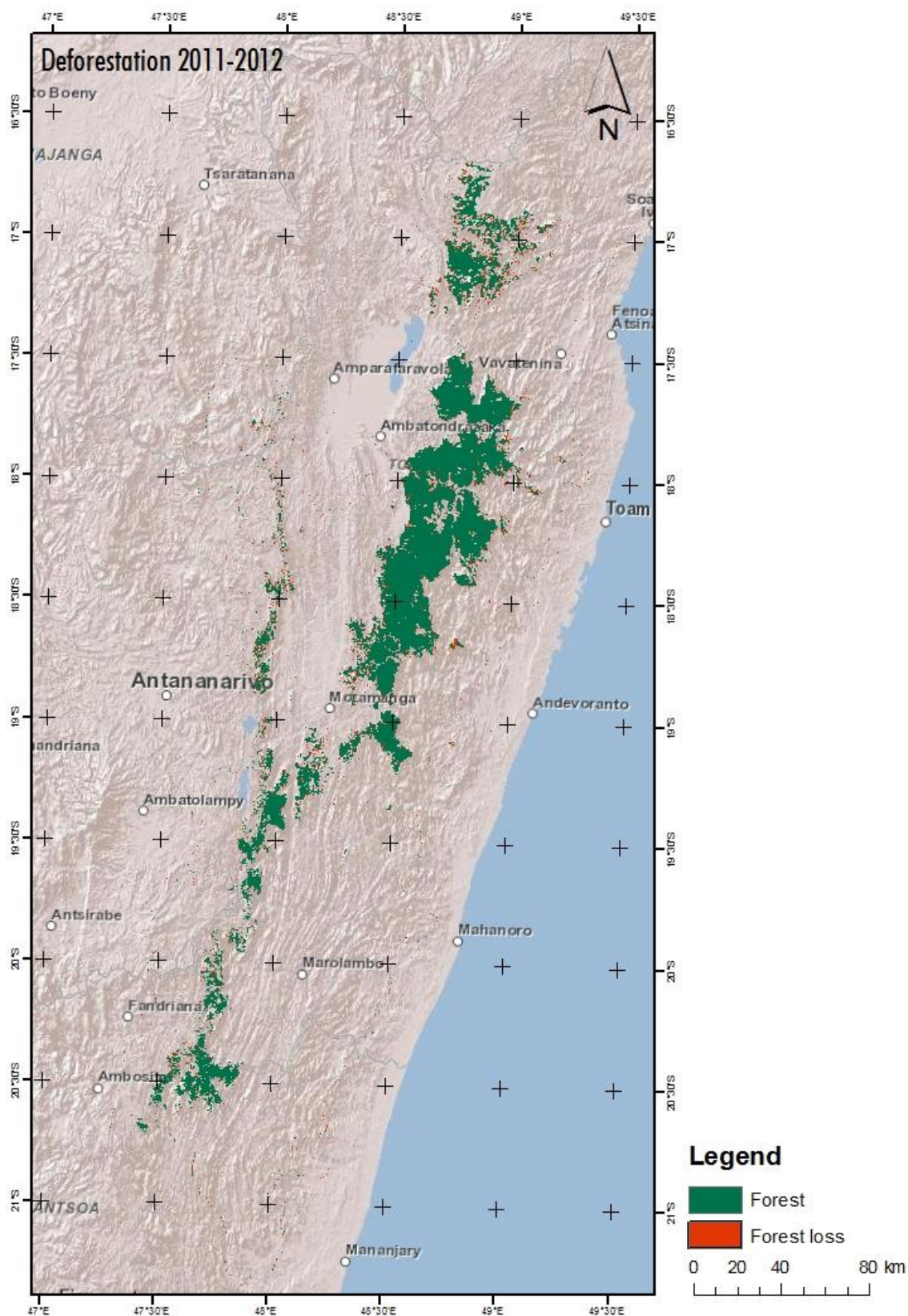
VM Figure 23c. Baseline Deforestation in the reference region for the period 2008-2009



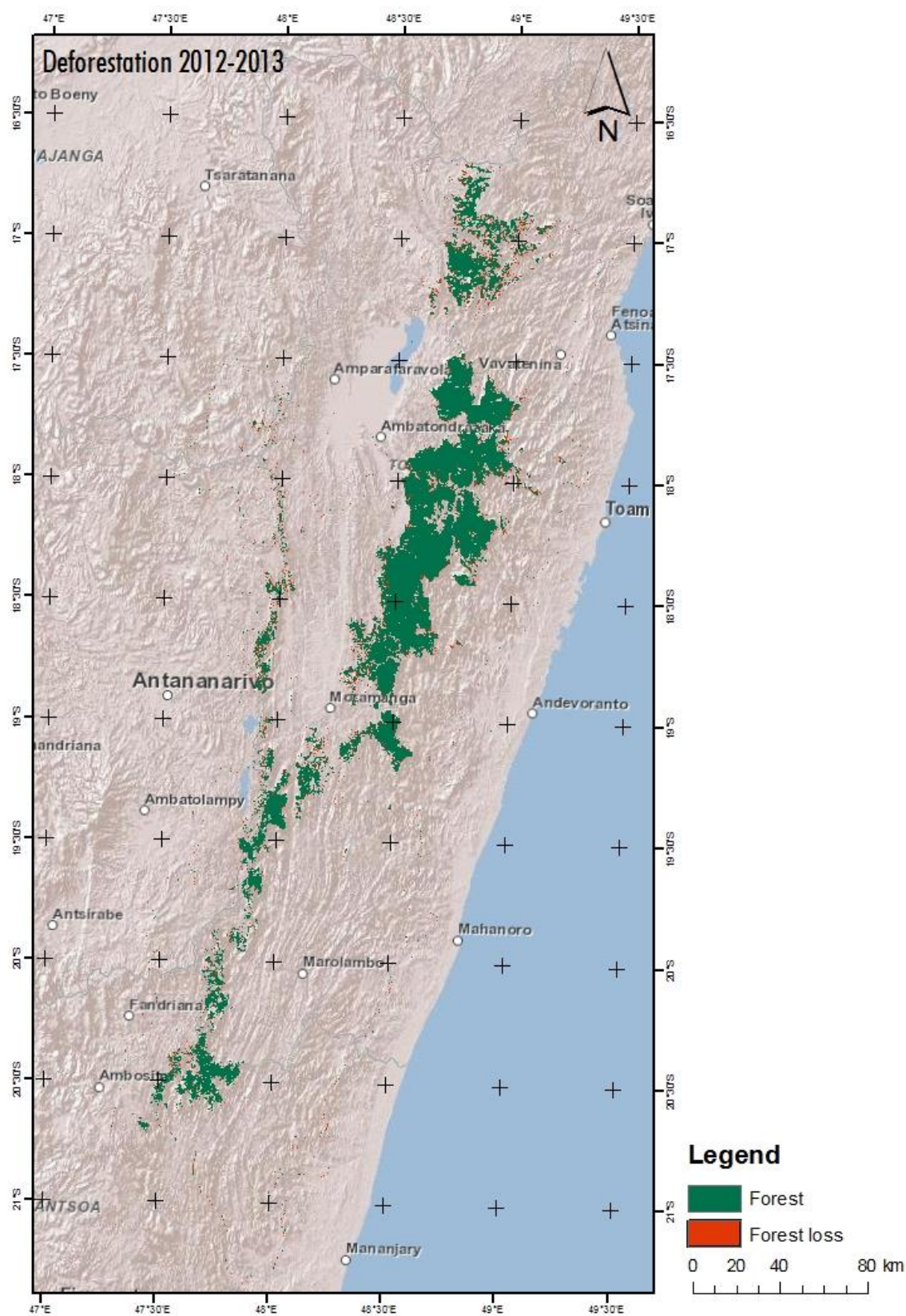
VM Figure 23d. Baseline Deforestation in the reference region for the period 2009-2010



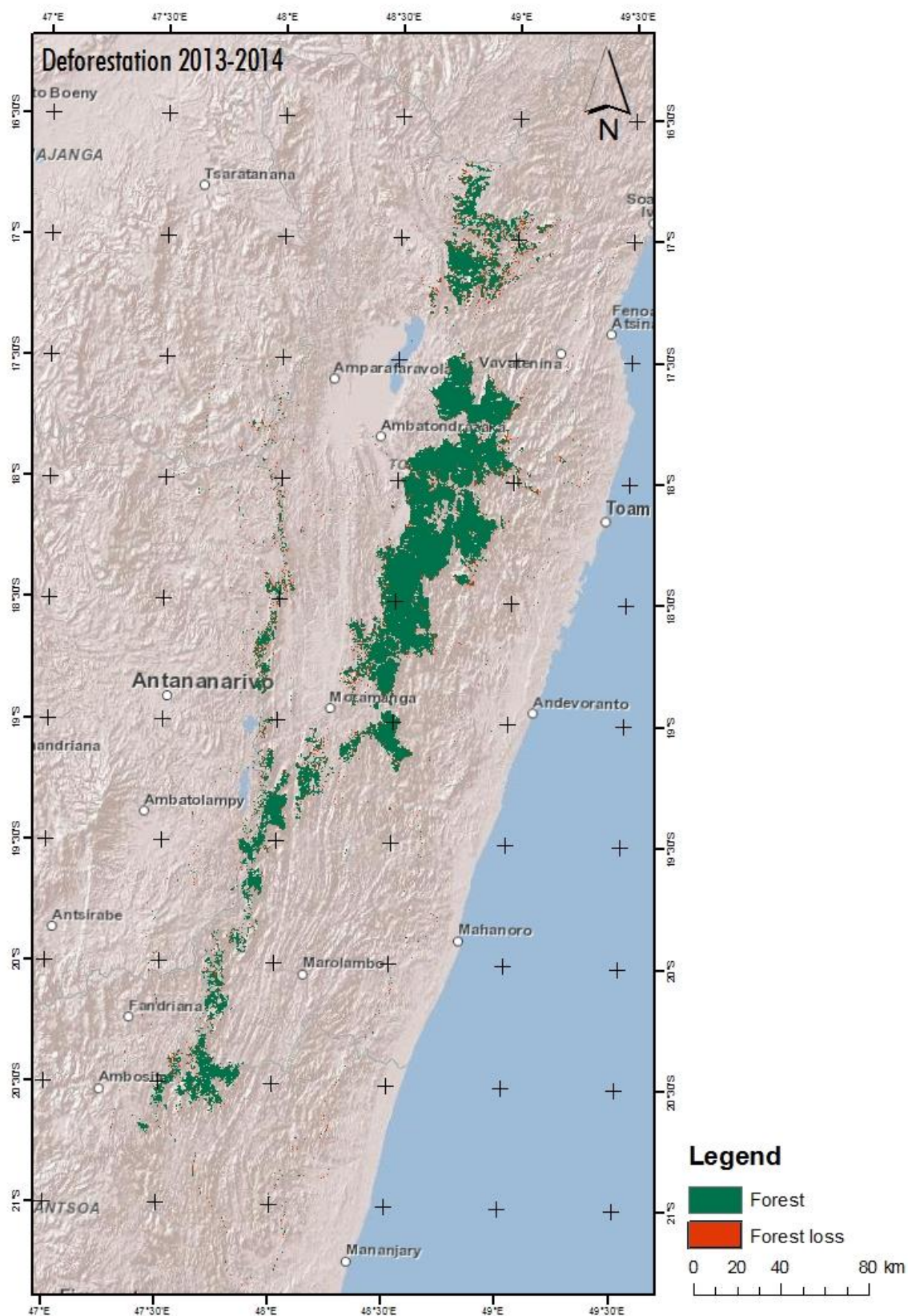
VM Figure 23e. Baseline Deforestation in the reference region for the period 2010-2011



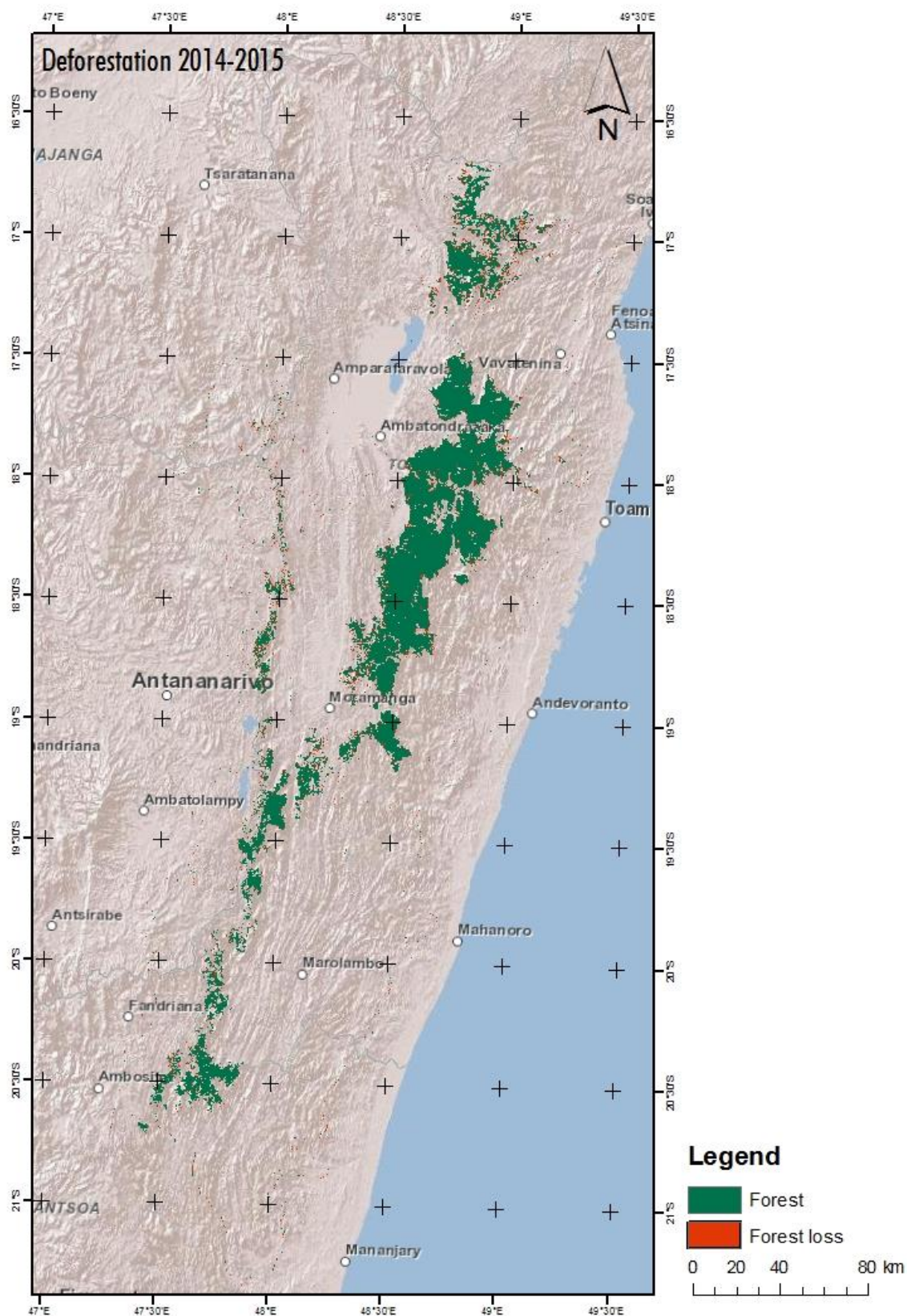
VM Figure 23f. Baseline Deforestation in the reference region for the period 2011-2012



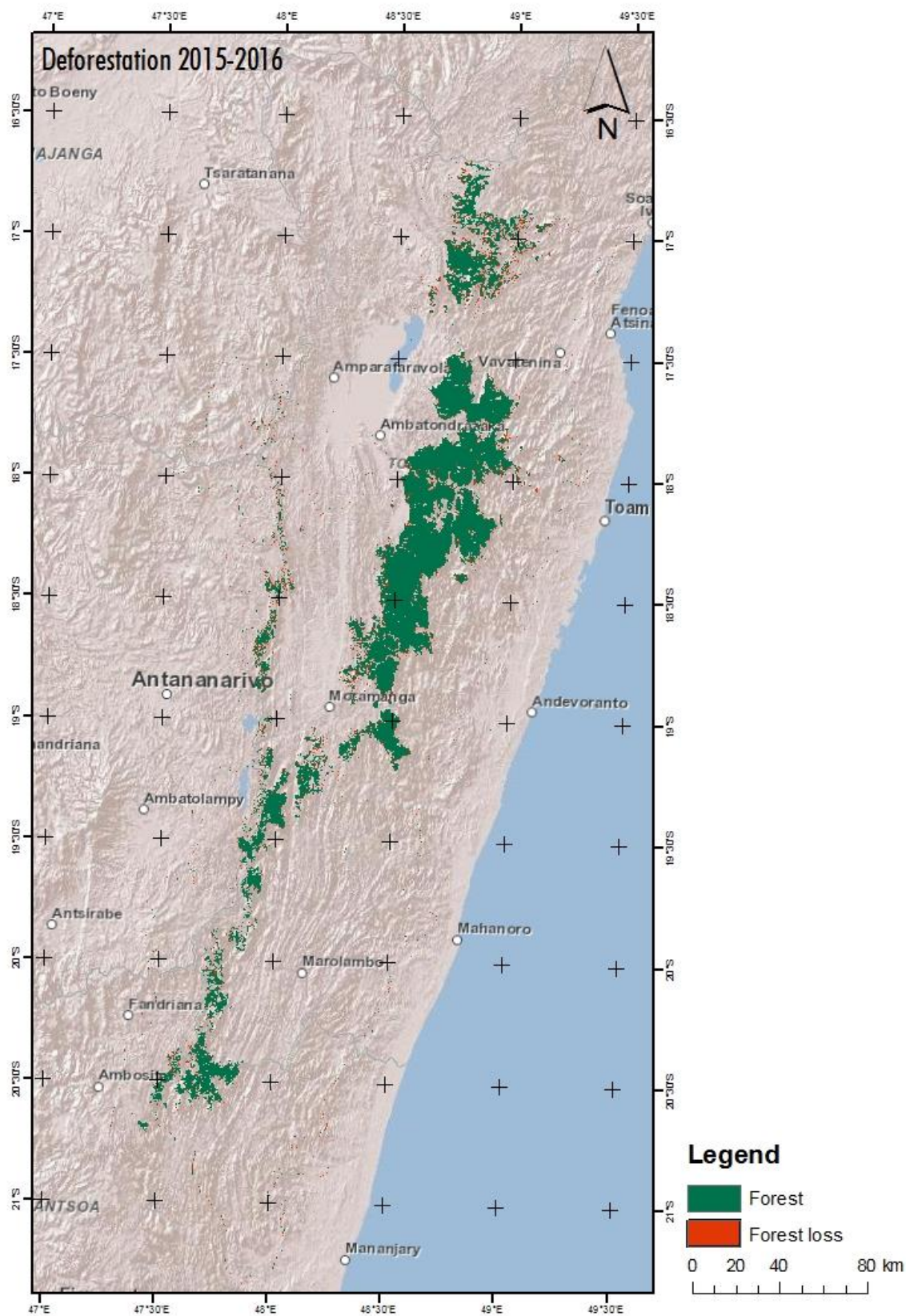
VM Figure 23g. Baseline Deforestation in the reference region for the period 2012-2013



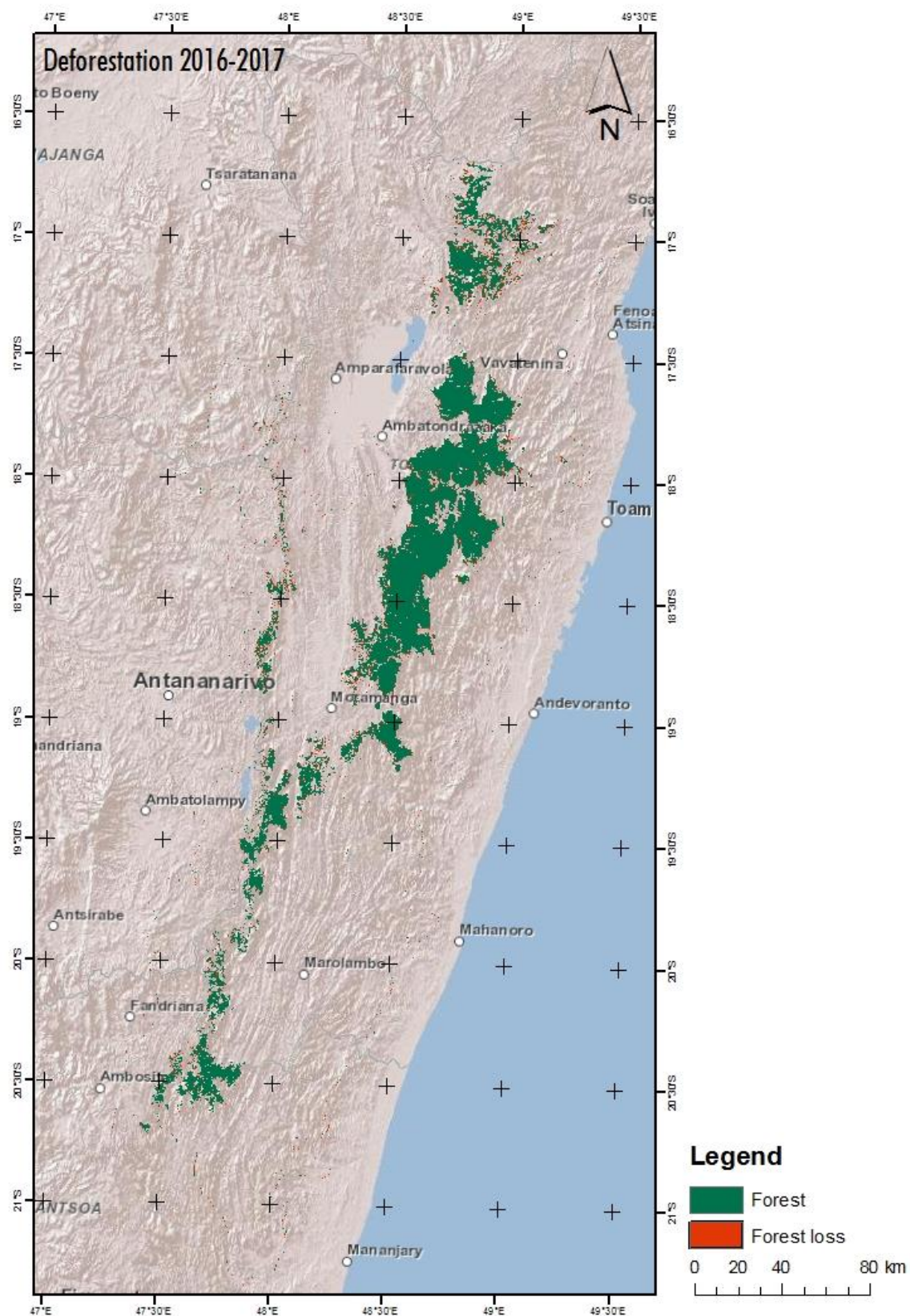
VM Figure 23h. Baseline Deforestation in the reference region for the period 2013-2014



VM Figure 23i. Baseline Deforestation in the reference region for the period 2014-2015



VM Figure 23j. Baseline Deforestation in the reference region for the period 2015-2016



VM Figure 23k. Baseline Deforestation in the reference region for the period 2016-2017

VM Step 5: Definition of the land-use and land-cover change component of the baseline

VM 5.1 Calculation of baseline activity data per forest class

In order to estimate the area in hectares of each forest class within the project area (Forest land Category A and Forest land Category B) deforested under the baseline scenario, we combined the maps of Annual Baseline Deforestation for 2008 - 2017 with a land cover map, depicting the spatial distribution of forest types in 2005. The results are shown in VM Table 11b and 11c. In the baseline scenario, the carbon stocks and boundaries of each forest class within the project area and leakage belt are assumed to remain constant. It's not expected that areas will lose carbon stocks due to degradation, logging for timber, charcoal production or fuel wood collection.

VM Table 11b. Annual areas deforested per forest class *icl* within the project area in the baseline case (baseline activity data per forest class)

Area deforested per forest class <i>icl</i> within the project area			Total baseline deforestation in the project area	
<i>ID_{icl}</i> > Name >	1	2	<i>ABSLPA_t</i> annual ha	<i>ABSLPA</i> cumulative ha
	Forest Land (Cat. A)	Forest Land (Cat. B)		
Project year <i>t</i>	ha	ha		
2008	542	2,089	2,632	2,632
2009	792	2,908	3,699	6,331
2010	1,030	3,644	4,675	11,006
2011	1,503	3,790	5,293	16,299
2012	1,899	3,519	5,418	21,717
2013	2,153	3,616	5,769	27,486
2014	2,352	2,773	5,125	32,612
2015	1,867	2,353	4,220	36,832
2016	1,799	2,269	4,068	40,900
2017	1,914	2,076	3,990	44,890

VM Table 11c. Annual areas deforested per forest class *icl* within the leakage belt in the baseline case (baseline activity data per forest class)

Area deforested per forest class <i>icl</i> within the leakage belt area		Total baseline deforestation in the leakage belt area	
<i>ID_{icl}</i> > Name >	1	<i>ABSLK_t</i> annual ha	<i>ABSLK</i> cumulative ha
	Forest Land		
Project year <i>t</i>	ha		
2008	4,707	4,707	4,707
2009	4,014	4,014	8,722
2010	2,902	2,902	11,624
2011	2,837	2,837	14,461

2012	2,623	2,623	17,083
2013	2,028	2,028	19,111
2014	1,963	1,963	21,075
2015	1,872	1,872	22,947
2016	1,982	1,982	24,929
2017	1,854	1,854	26,783

VM 5.2 Calculation of baseline activity data per post-deforestation forest class

The estimation of baseline activity data was analyzed using **Method 01**, where historical land use and land cover changes are assumed to be representative of future trends.

The land-use and land-cover map for the historical period was derived by interpreting Landsat imagery. This imagery has a spatial resolution of approximately 30 meters, thus allowing for an accurate distinction between closed-canopy forest and non-forest areas. Non-forest uses are largely comprised of Tavy cropland at various stages of the slash-and-burn cycle, entailing a succession of vegetation types from woody shrubs to grasses. Reflectance from this range of Tavy types are similar; furthermore the vegetation type is in constant transition, with the cropland – fallow – burn cycle lasting two to five years. There is consequently a high degree of uncertainty in separating these areas in the classification and the project considers only one non-forest land use class replacing forest vegetation. This is consistent with previous large-scale vegetation mapping of eastern Madagascar, where only one classification of secondary vegetation is identified after deforestation (Faramalala, 1995; Moat and Smith, 2007). Many authors have documented the long term persistence of this dynamic landscape that is dominated by secondary vegetation that is cut, burned and recovers biomass in an ongoing cycle over many years (Aubert et al., 2003; Serpantie et al., 2007; Styger et al., 2007; Styger et al., 2009). No further stratification of non-forest land uses is undertaken in the reference region, therefore only one zone represents the post-deforestation land use. The areas projected to be deforested in project area and leakage belt are reported in VM Table 13b, and 13c.

VM Table 13b. Annual areas of post-deforestation classes *fc*/ within the project area in the baseline case (baseline activity data per non-forest class)

Area established after deforestation per class <i>fc</i> / within the project area		Total baseline deforestation in the project area	
IDz	1	ABSLPA _t annual ha	ABSLPA cumulative ha
Name >	savoka		
Project year v	ha		
2008	2,632	2,632	2,632
2009	3,699	3,699	6,331
2010	4,675	4,675	11,006
2011	5,293	5,293	16,299
2012	5,418	5,418	21,717
2013	5,769	5,769	27,486

2014	5,125	5,125	32,612
2015	4,220	4,220	36,832
2016	4,068	4,068	40,900
2017	3,990	3,990	44,890

VM Table 13c. Annual areas of post-deforestation classes *fcI* within the leakage belt in the baseline case (baseline activity data per non-forest class)

Area established after deforestation per class <i>fcI</i> within the leakage belt		Total baseline deforestation in the leakage belt	
<i>ID_z</i>	1	<i>ABSLLK_t</i> annual ha	<i>ABSLLK</i> cumulative ha
Name >	savoka		
Project year <i>v</i>	ha		
2008	4,707	4,707	4,707
2009	4,014	4,014	8,722
2010	2,902	2,902	11,624
2011	2,837	2,837	14,461
2012	2,623	2,623	17,083
2013	2,028	2,028	19,111
2014	1,963	1,963	21,075
2015	1,872	1,872	22,947
2016	1,982	1,982	24,929
2017	1,854	1,854	26,783

VM 5.3 Calculation of baseline activity data per LU/LC change category

Section 5.3 is only applicable when Method 2 has been used to calculate of baseline activity data per post-deforestation forest class.

VM Step 6: Estimation of baseline carbon stock changes and non-CO₂ emissions

VM 6.1 Estimation of baseline carbon stock changes

VM 6.1.1 Estimation of average carbon densities

Average carbon stock estimates of the forest and non-forest classes in the Ankeniheny-Zahamena Corridor were derived through field measurements conducted in 2009, as no accurate existing data that meet the requirement from VM0015 were available. The field crews that conducted the measurements were trained by Winrock International on their Standard Operating Procedures (SOP) and most of the tools (excel spreadsheets with macros, field data forms, formulas for carbon calculation) were provided by Winrock specifically for use in Madagascar (Walker et al., 2008). These SOPs are based on the IPCC GPG for LULUCF (IPCC GPG, 2003) and adapted by Winrock based

on their experiences worldwide (Pearson et al., 2005). Details of the design, measurements and data collected are provided in a separate report describing this work that is available to the validator on request (Andrianarivelo et al, 2009).

Sampling design:

The size of CAZ meant that a fully randomized sampling of the area was not logistically feasible. VM0015 suggests that in case of *remote areas and areas with poor accessibility (either because of physical or social barriers such as unsafe areas) may be excluded for the location of sampling plots, using a transparent and conservative procedures, assuring the representativeness of the plots for the corresponding stratum* (see Supplementary Information - Sampling design of biomass inventory for CAZ) The project therefore adopted a semi-randomized/clustered randomized sampling design in which predetermined general areas known to be accessible were identified and then sample plots were located randomly within them. To ensure that the sampling included areas that were likely to be at risk of deforestation, we categorized the forest into areas where the IDRISI Land Change Modeler model being used predicted a loss of forest in the 30 years crediting period of the project and forests that were predicted to be persistent during the crediting period.

A preliminary field expedition was made to collect information from sample plots so that the variability of the biomass could be estimated. The objective of this preliminary visit was to determine the overall number of plots needed in the sampling design. During this preliminary field visit, the following parameters were measured in the field following the standard methodology described in the SOP:

- Biomass of trees
- Biomass of saplings
- Biomass of grasses and non tree species
- Biomass of dead wood
- Biomass of litter
- Time needed to get to a plot
- Time needed to finish a plot

For the preliminary field trip, the area of Raboana was chosen. The field trip was for one week and the field team worked to maximize the number of plots achieved. Potential sampling plots to visit in this preliminary visit were predetermined within the Raboana area using ESRI's ArcGIS and its Hawth's tool extension. Eighteen plots were sampled in total. Based on the preliminary data collected, the number of sample plots necessary to attain a certain precision in the biomass measurement was calculated using the formula by Pearson et al. (2005):

$$n = \frac{(N_1 x s_1)^2 + (N_2 x s_2)^2}{\frac{N^2 x E^2}{t^2} + (N_1 x V_1) + (N_2 x V_2)}$$

Where:

- | | |
|----|---|
| n: | Necessary sample plot number |
| t: | Student's t |
| s: | Standard deviation |
| V: | Variance |
| N: | Sample in stratum i |
| E: | Allowable Error (half of the confidence interval) |

We used this equation to calculate the minimum number of plots that were needed in the two categories of forest (i.e. “predicted to be lost” and “predicted to persist”). For the persistent forest the aim was to ensure that we achieved a 20% allowable error in the sampling; for areas where deforestation was predicted, the allowable error was fixed at 10%. To achieve these allowable errors and based on the variability in biomass that had been detected from the preliminary analysis, 10 plots were needed for the persistent forest and 35 plots were needed for the forest areas where deforestation was predicted.

Identification of sampling locations:

To choose the sampling points, 300 points were first identified based on a random distribution throughout CAZ (using ArcGIS Hawth's tool). Then 4 areas were chosen (Didy, Fierenena, Andasibe, Fetraomby) based on accessibility, as well as to provide a range of locations that represented the east and west sides of the corridor and the latitudinal gradient within the corridor (Figure 24). Points within these areas were retained as the sampling plots. Based on this approach, 35 plots were within the “predicted to be deforested” areas and 31 plots were in the “predicted to persist” areas. Hence the number of plots for both forest categories was higher than our minimum estimates to achieve allowable error and 66 plots were visited in total (Table 12).

Table 12. Coordinates of the sampling plots located in forest land – coordinates are in UTM Zone 38N.

Plot_ID	X (m)	Y (m)	Plot_ID	X (m)	Y (m)
defor11	877,183.88	2,013,438.07	Defor59	893,461.51	2,053,534.71
Defor12	876,712.25	2,010,134.11	Defor60	892,201.46	2,054,232.44
Defor13	876,442.81	2,009,605.42	Defor61	891,390.12	2,054,828.60
Defor14	877,601.52	2,007,392.34	Edge62	875,340.35	1,999,582.93
defor15	877,601.52	2,007,392.34	Edge65	876,999.93	2,016,692.37
Defor16	878,508.57	2,012,373.78	edge66	876,486.24	2,001,717.30
defor17	878,044.26	2,014,902.08	Edge67	875,683.81	2,015,662.97
Defor18	877,134.86	2,010,049.93	edge68	876,883.02	1,996,256.27
Defor19	878,424.23	2,010,053.42	edge70	876,489.31	2,016,617.77
Defor20	878,990.40	2,013,778.12	for03	879,519.74	2,000,051.60
Defor22	866,742.41	2,100,105.46	For04	878,506.59	2,002,630.86
Defor23	868,861.58	2,101,677.90	For05	875,888.37	1,999,421.02
Defor25	866,784.34	2,100,503.51	For06	875,175.66	1,995,727.75
Defor26	867,305.01	2,100,544.61	For62	898,205.79	2,067,524.90
Defor27	864,223.75	2,101,552.32	For63	899,021.21	2,067,283.39
Defor28	864,586.84	2,099,921.33	For64	898,424.40	2,068,850.90
Defor29	867,254.11	2,099,860.01	For65	899,283.45	2,068,764.35
Defor30	863,514.74	2,100,660.84	SAH01	866,293.78	2,047,720.35
Defor41	867,593.49	2,096,331.72	SAH02	866,313.43	2,047,920.87
Defor42	867,361.65	2,097,238.60	SAH03	866,571.16	2,048,267.60
Defor43	868,867.59	2,093,111.39	SAH04	866,520.40	2,048,004.90
Defor44	867,819.13	2,095,443.20	SAH05	866,031.64	2,048,672.90
Defor45	868,540.67	2,096,298.13	SAH06	865,976.34	2,048,493.25
Defor46	867,801.73	2,097,062.55	SAH07	865,757.94	2,048,239.66
Defor47	867,801.73	2,097,062.55	SAH08	865,930.20	2,048,295.31

Defor48	868,834.52	2,095,666.55	SAH09	867,617.74	2,048,838.92
Defor49	867,550.97	2,092,996.05	SAH10	867,450.56	2,048,977.33
Defor50	868,053.81	2,092,319.31	SAH11	868,073.89	2,048,949.34
Defor51	896,530.45	2,066,069.47	SAH12	868,531.69	2,048,822.71
Defor56	896,835.37	2,065,540.16	SAH13	867,604.54	2,049,827.06
Defor57	893,047.31	2,053,390.62	SAH14	867,373.87	2,049,754.86
Defor58	893,302.60	2,053,405.14			

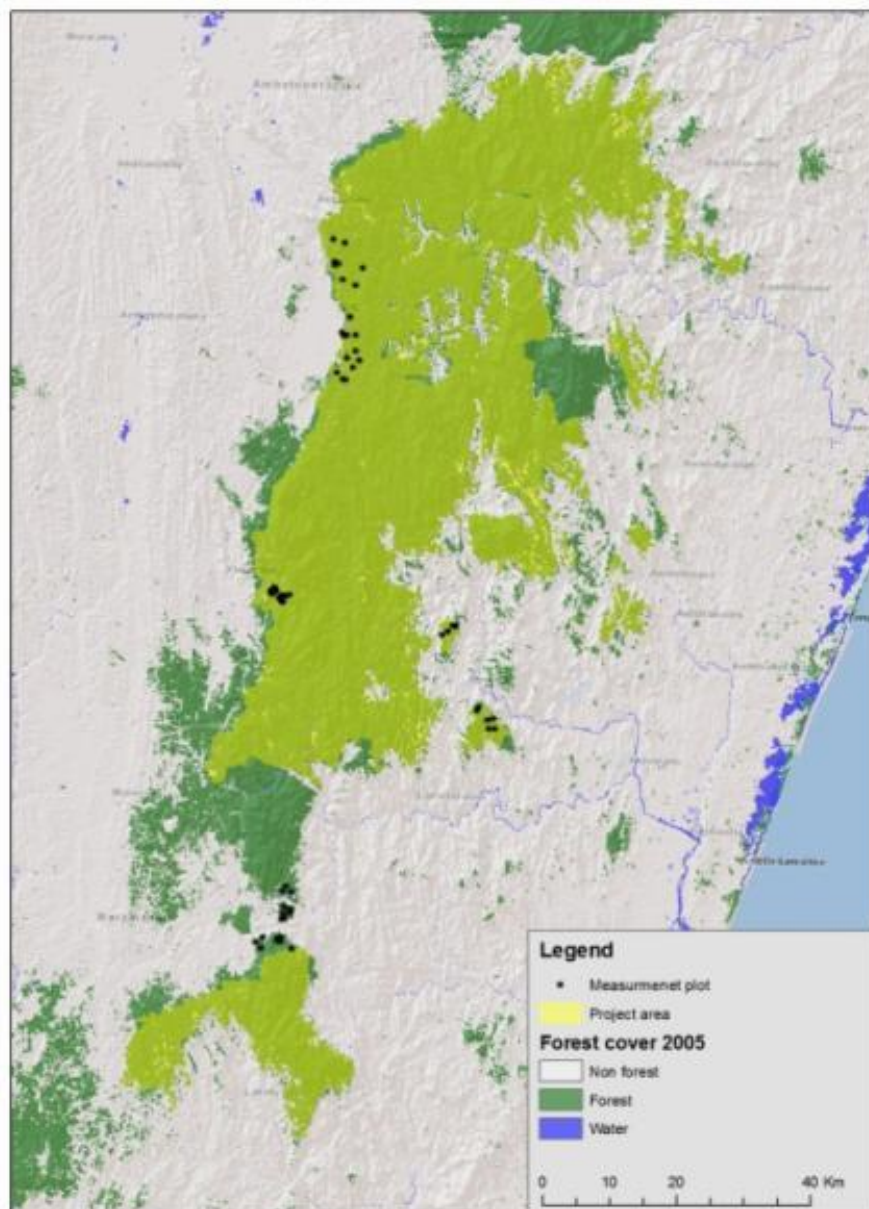


Figure 24. Location of carbon stock measurement plots within CAZ

Carbon stock evaluation:

At each sampling location biomass measurements were taken within a 20 m-radius circular plot using the standardized methodology provided by Wintock International (Walker et al., 2008). These measurements included above-ground living tree biomass, sapling biomass, standing and lying dead wood biomass. Based on the initial measurements, it was decided that it was not necessary to measure herbaceous biomass and litter, as these represented a very small portion of the biomass and were deemed negligible (less than 2 tons per hectare). We therefore did not include these carbon pools in future measurements. Below-ground biomass was derived from the above-ground biomass estimates using published conversion factors (Cairns et al., 1997; see section 4.1 Parameters available at validation). For the non-forest plots estimates of below-ground carbon density were based on the default root:shoot value for tropical shrubland (Table 4.4; IPCC, 2006). For above-ground biomass of the forest classes, initially the global equations of Chave et al. (2005) were used to estimate biomass as a function of tree diameter. However, as more recent, locally-derived allometric equations became available in the literature, they were replaced by the equations developed by Vieilledent et al. (2012) for moist-wet forests of Madagascar, specifically equation [Mada.II.1], described below:

$$[AGB]_{est} = \exp (-1.159 + 2.297 \log (D) + 0.83 \log (\rho))$$

Where:

AGB: Above Ground biomass (Kg)

D: Diameter at Breast Height (cm)

ρ : Wood density (g/cm³); a regional default value of 0.61 was used (Asner et al., 2012)

Results:

An initial analysis of the data identified a small number (4) of outliers. Since the three upper-boundary outliers detected in these plots would bias the average carbon stock to a higher value, we decided to conservatively remove them from the subsequent analyses and the carbon stock values used in the Project Description. To maintain the principle of a conservative calculation of biomass/carbon stock values, we did not remove the one outlier identified at the lower boundary. The final number of plots that was used for the biomass/carbon stock calculations is therefore 63.

Note that subsequent changes in the VM0015 methodology meant that the final model of baseline projected deforestation as used in the current Project Description is different from the model that was originally used to categorize forests into “projected to be deforested” and “projected to be persistent”. We therefore did not use the original model as stratification but instead used the data that had been collected from the sampling plots to test for relationships between areas with different biophysical characteristics and under different types of forest management that would justify stratifying the project area into separate classes that represent different average biomass or carbon stock values. Based on existing literature and expert knowledge, the parameters that we considered to be most likely to influence carbon stocks were: altitude, slope, longitude and latitude, management regime, and potential for deforestation. We assumed that the presence of patterns in the distribution of biomass/carbon stock would imply that stratification of the project area should be done, whereas the lack of detectable patterns implies that differences in carbon values at particular plots are part of natural variation and that no further stratification would be justifiable. All statistical analyses were done using the R statistical package and are available to the validator upon request.

Since we were not able to detect any associations between total carbon stocks and variables hypothesized to affect carbon stocks, we conclude that no stratification is necessary in the project area. Instead, it is clear that there is a broad range of natural variation in carbon stocks within CAZ but these changes probably come from multiple factors, probably also acting at a very small, localized

scale. As such a simple stratification is not possible. Instead we conclude that the project should use a single average value for biomass/carbon stock across the project area.

The carbon stock values (expressed as tCO₂/ha) that have been estimated for the forest class in the project area and leakage belt to the year of baseline deforestation (VM Table 15a.b). The boundaries of the forest land are assumed to remain the same and increases in carbon stocks are conservatively omitted. The results of the uncertainty assessments were less than 10% of the average value, therefore no discount was applied to the carbon stock of forest class (VM Table 15.a.b).

VM Table 15.a.b. Carbon stocks per hectare of initial forest classes icl existing in the project area and leakage belt - Estimated values and after discounts for uncertainties

project year t	Initial forest class <i>icl</i>							
	Name: 1, 2, 3							
	IDicl Forest land, Category A, and Category B							
	Average Carbon stock per hectare $\pm 90\%$ CI							
	Cabicl		Cbbicl		Cdwicl		Ctoticl	
	Cstock t CO ₂ e ha ⁻¹	$\pm 90\%$ CI t CO ₂ e ha ⁻¹	Cstock t CO ₂ e ha ⁻¹	$\pm 90\%$ CI t CO ₂ e ha ⁻¹	Cstock t CO ₂ e ha ⁻¹	$\pm 90\%$ CI t CO ₂ e ha ⁻¹	Cstock t CO ₂ e ha ⁻¹	$\pm 90\%$ CI t CO ₂ e ha ⁻¹
2008	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2009	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2010	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2011	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2012	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2013	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2014	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2015	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2016	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0
2017	608.6	40.7	113.3	6.9	54.4	8.9	776.3	63.0

Long-term (20 years) average carbon stocks of post-deforestation classes

Tavy (slash-and-burn cultivation) is the principal form of cultivation in the reference region and a traditional practice in eastern Madagascar. Around the project, subsistence farmers clear the forest, burned and rice is then cultivated for a season, usually three years, natural regeneration follows the rice harvest for 4-5 years, and this cycle is repeated. The short period left for regeneration makes this practice unsustainable and after few cycles the production is very low.

The carbon stock of post-deforestation class was estimated based on a study of Tavy cycle in the Mantadia-Zahamena rainforest corridor conducted by Styger et al. (2006 and 2009). The authors carried out field survey to measure the biomass content in different fallow cycles of different ages. Their results show that the first fallow cycle is dominated by *Trema orientalis* with carbon content of 15.7 tCO₂ at year 3 and 49 tCO₂ at year 5. The second cycle is dominated by *Psiadia altissima* with 27 tCO₂ at year 3 and 57.9 tCO₂ at year 5 and the third cycle by *Rubus moluccanus* (29.2 tCO₂)

VM Table 16 summarizes the results of the long-term (20 years) average carbon stocks of post-deforestation classes. Note that, the project opted for using values from literature, an uncertainty discount factor of 30% was added to the average carbon stock.

VM Table 16. Long-term (20-years) average carbon stocks per hectare of post-deforestation LU/LC classes present in the reference region

project year t	savoka cycle	Post deforestation class <i>fcl</i>					
		Name: 1					
		ID <i>fcl</i> savoka					
		Average Carbon stock per hectare $\pm$ 90% CI					
C<i>abicl</i>		C<i>bbicl</i>		C<i>toticl</i>			
Cstock	$\pm$ 90% CI	Cstock	$\pm$ 90% CI	Cstock	$\pm$ 90% CI		
t CO ₂ e ha ⁻¹	t CO ₂ e ha ⁻¹	t CO ₂ e ha ⁻¹	t CO ₂ e ha ⁻¹	t CO ₂ e ha ⁻¹	t CO ₂ e ha ⁻¹		
t	rice	18.3	-	4.5	-	22.8	-
t+1	rice	18.3	-	4.5	-	22.8	-
t+2	rice	18.3	-	4.5	-	22.8	-
t+3	1st cycle	15.7	-	0.7	-	16.4	-
t+4	1st cycle	15.7	-	0.7	-	16.4	-
t+5	1st cycle	15.7	-	0.7	-	16.4	-
t+6	1st cycle	49.0	-	0.7	-	49.7	-
t+7	1st cycle	49.0	-	0.7	-	49.7	-
t+8	rice	18.3	-	4.5	-	22.8	-
t+9	rice	18.3	-	4.5	-	22.8	-
t+10	2nd cycle	27.0	-	0.3	-	27.3	-
t+11	2nd cycle	27.0	-	0.3	-	27.3	-
t+12	2nd cycle	27.0	-	0.3	-	27.3	-
t+13	2nd cycle	57.9	-	0.3	-	58.2	-
t+14	2nd cycle	57.9	-	0.3	-	58.2	-
t+15	rice	18.3	-	4.5	-	22.8	-
t+16	rice	18.3	-	4.5	-	22.8	-
t+17	3rd cycle	29.2	-	1.0	-	30.2	-
t+18	3rd cycle	29.2	-	1.0	-	30.2	-
t+19	3rd cycle	29.2	-	1.0	-	30.2	-
t+20	3rd cycle	29.2	-	1.0	-	30.2	-
average		27.9		1.9		29.9	
average to be used in calculations		36.3		2.5		38.8	

VM 6.1.2 Calculation of baseline carbon stock changes

Following the VCS AFOLU Requirements to consider the decay of carbon stock in soil carbon, below-ground biomass, dead wood and harvested wood products in the estimation of baseline carbon stock changes, VM0015 methodologies provides a liner function to account for theses decays in initial

forest classes and increase in the post-deforestation classes. In case of CAZ REDD project, this requirement applies as follow:

Above ground biomass:

- Forest class immediate releases of 100% of the carbon stock at the end of the year of the deforestation;
- Post-deforestation class observes a linear function increasing from 0 tCO₂/ha at the year of the deforestation to 100% at year 10 after the deforestation event. It's assumed that 1/10th of the final carbon stock are accumulated each year.

Below ground biomass and dead wood:

- Forest class immediate releases of 1/10th annually of the initial carbon stock from year of the deforestation event;
- Post-deforestation class observes a linear function increasing from 0 tCO₂/ha at the year of the deforestation to 100% at year 10 after the deforestation event. It's assumed that 1/10th of the final carbon stock are accumulated each year.

Carbon stock change factors are summarized on VM Table 20.a. and 20.b.

VM Table 20.a. Carbon stock change factors for initial forest classes icl (Method 1)

Year after deforestation		$\Delta C_{ab\ icl,t}$	$\Delta C_{bb\ icl,t}$	$\Delta C_{dw\ icl,t}$	$DC_{tot\ icl,t}$
1	t	-608.6	-11.3	-5.4	-625.4
2	t+1	0	-11.3	-5.4	-16.8
3	t+2	0	-11.3	-5.4	-16.8
4	t+3	0	-11.3	-5.4	-16.8
5	t+4	0	-11.3	-5.4	-16.8
6	t+5	0	-11.3	-5.4	-16.8
7	t+6	0	-11.3	-5.4	-16.8
8	t+7	0	-11.3	-5.4	-16.8
9	t+8	0	-11.3	-5.4	-16.8
10	t+9	0	-11.3	-5.4	-16.8
11	t+10	0	0	0	0
12	t+11	0	0	0	0
13	t+12	0	0	0	0
14	t+13	0	0	0	0
15	t+14	0	0	0	0
16	t+15	0	0	0	0
17	t+16	0	0	0	0
18	t+17	0	0	0	0
19	t+18	0	0	0	0
20	t+19	0	0	0	0

VM Table 20.b. Carbon stock change factors for final classes fcl or zones z (Method 1)

Year after deforestation		$\Delta Cab_{z,t}$	$\Delta Cbb_{z,t}$	$DCdw_{z,t}$	$DCtot_{z,t}$
1	t	3.6	0.3	0.0	3.9
2	t+1	3.6	0.3	0.0	3.9
3	t+2	3.6	0.3	0.0	3.9
4	t+3	3.6	0.3	0.0	3.9
5	t+4	3.6	0.3	0.0	3.9
6	t+5	3.6	0.3	0.0	3.9
7	t+6	3.6	0.3	0.0	3.9
8	t+7	3.6	0.3	0.0	3.9
9	t+8	3.6	0.3	0.0	3.9
10	t+9	3.6	0.3	0.0	3.9
11	t+10	0	0	0	0
12	t+11	0	0	0	0
13	t+12	0	0	0	0
14	t+13	0	0	0	0
15	t+14	0	0	0	0
16	t+15	0	0	0	0
17	t+16	0	0	0	0
18	t+17	0	0	0	0
19	t+18	0	0	0	0
20	t+19	0	0	0	0

VM 6.1.3 Calculation of baseline carbon stock changes

Method 1 was used to calculate the baseline carbon stock change. Carbon stock changes in the project area were estimated by using the (VM0015 equation 10):

$$\begin{aligned}
 \Delta C_{BSLPA}_t = & \sum_{p=1}^P \left(\sum_{icl=1}^{Icl} ABSLPA_{icl,t} * \Delta Cp_{icl,t=t*} - \sum_{z=1}^Z ABSLPA_{z,t} * \Delta Cp_{z,t=t*} \right. \\
 & + \sum_{icl=1}^{Icl} ABSLPA_{icl,t-1} * \Delta Cp_{icl,t=t*+1} - \sum_{z=1}^Z ABSLPA_{z,t-1} * \Delta Cp_{z,t=t*+1} \\
 & + \sum_{icl=1}^{Icl} ABSLPA_{icl,t-2} * \Delta Cp_{icl,t=t*+2} - \sum_{z=1}^Z ABSLPA_{z,t-2} * \Delta Cp_{z,t=t*+2} + \dots \\
 & \left. + \sum_{icl=1}^{Icl} ABSLPA_{icl,t-19} * \Delta Cp_{icl,t=t*+19} - \sum_{z=1}^Z ABSLPA_{z,t-19} * \Delta Cp_{z,t=t*+19} \right)
 \end{aligned}$$

Where:

ΔC_{BSLPA_t}	Total baseline carbon stock change within the project area at year t ; tCO ₂ -e
$ABSLPA_{icl,t}$	Area of initial forest class icl deforested at time t within the project area in the baseline case; ha
$ABSLPA_{icl,t-1}$	Area of initial forest class icl deforested at time $t-1$ within the project area in the baseline case; ha
...	
$ABSLPA_{icl,t=t-19}$	Area of initial forest class icl deforested at time $t-19$ within the project area in the baseline case; ha
$\Delta C_{p_{icl,t=t^*}}$	Average carbon stock change factor for carbon pool p in the initial forest class icl applicable at time t (as per Table 20.a); tCO ₂ -e ha ⁻¹
$\Delta C_{p_{icl,t=t^*+1}}$	Average carbon stock change factor for carbon pool p in the initial forest class icl applicable at time $t=t^*+1$ (= 2 nd year after deforestation, as per Table 20.a); tCO ₂ -e ha ⁻¹
...	
$\Delta C_{p_{icl,t=t^*+19}}$	Average carbon stock change factor for carbon pool p in the initial forest class icl applicable at time $t=t^*+19$ (20 th year after devorestation, (as per Table 20.a); tCO ₂ -e ha ⁻¹
$ABSLPA_{z,t}$	Area of the zone z “deforested” at time t within the project area in the baseline case; ha
$ABSLPA_{z,t-1}$	Area of the zone z “deforested” at time $t-1$ within the project area in the baseline case; ha
...	
$ABSLPA_{z,t-19}$	Area of the zone z “deforested” at time $t-19$ within the project area in the baseline case; ha
$\Delta C_{p_{z,t=t^*}}$	Average carbon stock change factor for carbon pool p in zone z applicable at time $t = t^*$ (as per Table 20.b); tCO ₂ -e ha ⁻¹
$\Delta C_{p_{z,t=t^*+1}}$	Average carbon stock change factor for carbon pool p in zone z applicable at time $t = t^*+1$ ((= 2 nd year after deforestation, as per Table 20.b); tCO ₂ -e ha ⁻¹
...	
$\Delta C_{p_{z,t=t^*+19}}$	Average carbon stock change factor for carbon pool p in zone z applicable at time $t = t^*+19$ ((= 20 th year after deforestation, as per Table 20.b); tCO ₂ -e ha ⁻¹
icl	1, 2, 3 ... ICl initial (pre-deforestation) forest classes; dimensionless
z	1, 2, 3 ... Z zones; dimensionless
p	1, 2, 3 ... P carbon pools included in the baseline; dimensionless
t	1, 2, 3 ... T , a year of the proposed project crediting period; dimensionless
t^*	the year at which the area $ABSLPA_{icl,t}$ is deforested in the baseline case.

The total baseline carbon stock changes in the project area and leakage belt are summarized in VM Table 21.b.4. and VM Table 21.c.4. Intermediate tables were presented to the validators.

VM Table 21.b.4. Total baseline carbon stock change in the project area

Project year	Total net carbon stock change in the project area	
	$\Delta C_{BSLPA_{icl,t}}$	$\Delta C_{BSLPA_{icl}}$
	annual	cumulative
	tCO ₂ -e	tCO ₂ -e
2008	-1,635,559	-1,635,559
2009	-2,350,992	-3,986,551
2010	-3,021,084	-7,007,635
2011	-3,475,947	-10,483,581
2012	-3,623,939	-14,107,520
2013	-3,918,130	-18,025,649
2014	-3,581,367	-21,607,016
2015	-3,069,579	-24,676,595
2016	-3,016,742	-27,693,337
2017	-3,039,837	-30,733,174

VM Table 21.c.4. Total baseline carbon stock change in the leakage belt

Project year	Total net carbon stock change in the project area	
	$\Delta C_{BSLPA_{icl,t}}$	$\Delta C_{BSLPA_{icl}}$
	annual	cumulative
	tCO ₂ -e	tCO ₂ -e
2008	-2,925,430	-2,925,430
2009	-2,543,976	-5,469,406
2010	-1,885,726	-7,355,132
2011	-1,881,701	-9,236,833
2012	-1,781,295	-11,018,128
2013	-1,435,552	-12,453,680
2014	-1,420,366	-13,874,046
2015	-1,387,394	-15,261,441
2016	-1,463,689	-16,725,129
2017	-1,444,092	-18,169,221

VM 6.2 Baseline non-CO₂ emissions from forest fires

Since most of the forest in this region is cleared by *Tavy* (slash-and-burn), a significant amount of non-CO₂ emissions result from the burning of felled trees. The allowed additional emissions in the VCS are only CH₄. The methodology provides explicit guidance on estimating these non-CO₂ emissions (see Equation 12 and 13 of VM0015). It recommends using the formulas provided in the IPCC GPG, which provide formula parameters for the molecular ratios and differences in climate-warming forcing. The project is required to provide an estimate of the fraction of the vegetation that is burned and the combustion efficiency of the burning. Based on IPCC default values for tropical forests (IPCC 2006 GHGNI, Table 2.6) (Kaufman *et al.*, 1992), we assume that 32 percent of the felled biomass is burned. Of the biomass that is burned, approximately 50 percent is not emitted as CO₂; rather it is retained in the ash, as suggested by VM0015 based on IPCC default values (IPCC 2003 GPG, Table 3.A.14). We thus use a value of 50 percent for the combustion efficiency of the biomass burning. For the 'proportion of forest area burned during the historical reference period' (*Fburnt* parameter), we assume that this is 100% of the area deforested, since the principal cause of deforestation is *Tavy* which traditionally includes slash and burn. VM Table 23 provides the parameters used and the final amount of total non-CO₂ GHGs emitted per hectare of deforestation, in units of CO₂e. The baseline emissions of non-CO₂ GHGs from forest fires are estimated as the product of the deforestation areas from VM Table 11 and the per-hectare non-CO₂ GHG emissions from VM Table 23. These are provided in VM Table 24 for the project site.

VM Table 23. Parameters used to calculate non-CO₂ emissions from forest fires

IDcl	Initial Forest Class Name	Parameters										tCO ₂ e ha ⁻¹ ECO2-ab	tCO ₂ e ha ⁻¹ ECO2-dw	tCO ₂ e ha ⁻¹ ECO2-l	tCO ₂ e ha ⁻¹ EBBCO2-tot	tCO ₂ e ha ⁻¹ EBBnN2O _{icl}	tCO ₂ e ha ⁻¹ EBBCH4 _{icl}	tCO ₂ e ha ⁻¹ EBBtot _{icl}
		Fburnt _{icl} %	tCO ₂ e ha ⁻¹ Cab	tCO ₂ e ha ⁻¹ Cdw	tCO ₂ e ha ⁻¹ Cl	Pburnt _{ab,icl} %	Pburnt _{dw,icl} %	Pburnt _{l,icl} %	CE _{ab,icl} %	CE _{dw,icl} %	CE _{l,icl} %							
1	Forest Land	100	608.6	54.4	-	32	32	-	50	50	-	97.4	8.7	-	106.1	-	9.7	9.7
2	Forest Land (Cat. B)	100	608.6	54.4	-	32	32	-	50	50	-	97.4	8.7	-	106.1	-	9.7	9.7
3	Forest Land (Cat. C)	100	608.6	54.4	-	32	32	-	50	50	-	97.4	8.7	-	106.1	-	9.7	9.7

VM Table 24. Baseline non-CO₂ emissions from forest fires in the project area

Project year	Emissions of non-CO ₂ gases from baseline forest fires				Total baseline non-CO ₂ emissions from forest fires in the project area	
	ID _{icl} = Cat A		ID _{icl} = Cat B		annual EBBBSLPA _t tCO ₂ -e	cumulative EBBBSLPA tCO ₂ -e
	ABSLPA _{icl,t} ha	EBBBSL _t tCO ₂ -e ha ⁻¹	ABSLPA _{icl,t} ha	EBBBSL _t tCO ₂ -e ha ⁻¹		
2008	542	542	-9.7	2,089	-9.7	-25,582
2009	792	792	-9.7	2,908	-9.7	-35,962
2010	1,030	1,030	-9.7	3,644	-9.7	-45,441
2011	1,503	1,503	-9.7	3,790	-9.7	-51,452
2012	1,899	1,899	-9.7	3,519	-9.7	-52,667
2013	2,153	2,153	-9.7	3,616	-9.7	-56,084
2014	2,352	2,352	-9.7	2,773	-9.7	-49,823
2015	1,867	1,867	-9.7	2,353	-9.7	-41,022
2016	1,799	1,799	-9.7	2,269	-9.7	-39,545
2017	1,914	1,914	-9.7	2,076	-9.7	-38,787

3.2 Project Emissions

VM Step 7: *Ex ante* estimation of actual carbon stock changes and non-CO₂ emissions in the project area

VM 7.1 *Ex ante* estimation of actual carbon stock changes

VM 7.1.1 *Ex ante* estimation of actual carbon stock changes due to planned activities

The project area is made up of two forest management regimes:

1. Strict conservation zones, where no extractive activities are permitted, correspond to Forest Land (Cat. A). The accessible forest areas of the strict conservation zone were previously exploitable by the local communities and would have become increasingly used in the baseline as more peripheral forest was lost. Protection of these areas within the strict conservation zone without harvesting may lead to an increase in carbon stocks due to planned project activities. This increase is conservatively ignored and will not be included in the *ex post* monitoring.
2. Sustainable use forest areas, where local residents can harvest some timber and fuelwood for household use according to defined sustainable quotas, corresponding to Forest Land (Cat. B). These activities will not decrease carbon stocks in comparison to the baseline as the quotas correspond to the existing level of exploitation of the forest and agreed upon by the local communities according to their historical use of the forest. The carbon stock measurements for the project were carried out on the edge of the corridor and in areas of forest in proximity to local communities. Such areas will have already experienced timber harvesting and firewood collection, and therefore the carbon stocks the project uses in the

estimation emissions reductions reflect the existing use of the forest. The full assessment of the impact of legal and illegal forest degradation is described in the Supplementary Information - Impact of legal and illegal harvesting on forest degradation in the CAZ REDD project area.

The AUD project activity involves no planned deforestation, causes no decrease in carbon stocks above the baseline and the project proponent does not seek to be credited for carbon stock increases.

VM 7.1.2 Ex ante estimation of carbon stock changes due to unavoidable unplanned deforestation within the project area

The actual carbon stock changes and GHG emissions will be measured and reported through the verification process. Here, under the assumption of project effectiveness and following the methodology, the *ex ante* carbon stock changes within the project area are estimated by multiplying the annual total baseline carbon stock change by an Effectiveness Index (EI). EI ranges from 0 (no effectiveness) to 1 (maximum effectiveness).

The Effectiveness Index was conservatively estimated based on project implementation activities. We assume that in the first year we would have an effectiveness of 0.2 and a 0.84 in the year 2017. The yearly increment on the EI was proportional to the projected costs (also used as input in the financial viability analysis) adding up to 0.84, which represents the proportional decrease of the deforestation rate when compared to a well-established protected area (Table 12). The deforestation rate inside a well-established protected area is 0.20%/y, being a 84% reduction of the historical deforestation rate within CAZ (1,26%/y).

Table 12. Ex ante deforestation rate and project efficiency

Project year	Effectiveness. Index	
	EI	%
2007	0.20	20
2008	0.27	27
2009	0.30	30
2010	0.34	34
2011	0.37	37
2012	0.39	39
2013	0.53	53
2014	0.61	61
2015	0.69	69
2016	0.76	76
2017	0.84	84

VM 7.1.3 Ex ante estimated net actual carbon stock changes in the project area

The *ex ante* assessments of the net carbon stock change in the project area were done based on Equation (16) of VM0015 and are reported in VM Table 27.

$$\Delta\text{CUDdPA}_t = \Delta\text{CBSL}_t * (1 - \text{EI})$$

Where:

ΔCUDdPA_t Total *ex ante* actual carbon stock change due to unavoided unplanned deforestation at year *t* in the project area; tCO₂-e

ΔCBSL_t Total baseline carbon stock change at year *t* in the project area; tCO₂-e

EI Ex ante estimated Effectiveness Index; %

T 1, 2, 3 ... *t*, a year of the proposed project crediting period; dimensionless

VM Table 27. *Ex ante* estimated net carbon stock change in the project area under the project scenario

Project year	Total carbon stock decrease due to planned activities		Total carbon stock increase due to planned activities		Total carbon stock decrease due to unavoided unplanned deforestation		Total carbon stock change in the project case	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	ΔCPAdPA_t tCO ₂ -e	ΔCPAdPA tCO ₂ -e	ΔCPAiPA_t tCO ₂ -e	ΔCPAiPA tCO ₂ -e	ΔCUDdPA_t tCO ₂ -e	ΔCUDdPA tCO ₂ -e	ΔCPSPA_t tCO ₂ -e	ΔCPSPA tCO ₂ -e
2008	0	0	0	0	-1,199,522	-1,199,522	-1,199,522	-1,199,522
2009	0	0	0	0	-1,647,057	-2,846,579	-1,647,057	-2,846,579
2010	0	0	0	0	-2,003,282	-4,849,862	-2,003,282	-4,849,862
2011	0	0	0	0	-2,196,997	-7,046,858	-2,196,997	-7,046,858
2012	0	0	0	0	-2,220,095	-9,266,954	-2,220,095	-9,266,954
2013	0	0	0	0	-1,830,994	-11,097,948	-1,830,994	-11,097,948
2014	0	0	0	0	-1,398,306	-12,496,254	-1,398,306	-12,496,254
2015	0	0	0	0	-958,047	-13,454,301	-958,047	-13,454,301
2016	0	0	0	0	-710,983	-14,165,284	-710,983	-14,165,284
2017	0	0	0	0	-482,514	-14,647,797	-482,514	-14,647,797

VM 7.2 Ex ante estimation of actual non-CO₂ emissions from forest fires

Ex-ante non-CO₂ emissions from biomass burning were estimated based on Equation (17) of VM0015, by multiplying the baseline emissions by the factor (1 – EI), where EI is the ex ante estimated Effectiveness Index. The results are presented in VM Table 28.

$$EBBPSPA_t = EBBBSPA_t * (1 - EI)$$

Where:

EBBPSPA_t Total ex ante actual non-CO₂ emissions from forest fire due to unavoided unplanned deforestation at year t in the project area; tCO₂e

EBBBSPA_t Total non-CO₂ emissions from forest fire at year t in the project area; tCO₂e

EI Ex ante estimated Effectiveness Index; %

t 1, 2, 3 ... T, a year of the proposed project crediting period; dimensionless

VM Table 28. Total ex ante estimated actual emissions of non-CO₂ gasses due to forest fires in the project area

Project year	Total ex ante estimated actual non-CO ₂ emissions from forest fires in the project area	
	EBBPSPA _t annual tCO ₂ -e	EBBPSPA Cumulative tCO ₂ -e
2008	-18,762	-18,762
2009	-25,194	-43,956
2010	-30,132	-74,088
2011	-32,520	-106,609
2012	-32,265	-138,873
2013	-26,209	-165,082
2014	-19,453	-184,535
2015	-12,803	-197,338
2016	-9,320	-206,658
2017	-6,157	-212,815

VM 7.3 Total ex ante estimations for the project area

VM Table 29. Total ex ante estimated actual net carbon stock changes and emissions of non-CO₂ gasses due to forest fires in the project area

Project year	Total ex ante carbon stock decrease due to planned activities		Total ex ante carbon stock increase due to planned activities		Total ex ante carbon stock decrease due to unavoided unplanned deforestation		Total ex ante net carbon stock change		Total ex ante estimated actual non-CO ₂ emissions from forest fires in the project area	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPA_{dPA,t}$ tCO ₂ -e	ΔCPA_{dPA} tCO ₂ -e	$\Delta CPA_{iPA,t}$ tCO ₂ -e	ΔCPA_{iPA} tCO ₂ -e	$\Delta CUD_{dPA,t}$ tCO ₂ -e	ΔCUD_{dPA} tCO ₂ -e	$\Delta CPSPA_t$ tCO ₂ -e	$\Delta CPSPA$ tCO ₂ -e	$EBBPSPA_t$ tCO ₂ -e	$EBBPSPA$ tCO ₂ -e
2008	0	0	0	0	-1,199,522	-1,199,522	-1,199,522	-1,199,522	-18,762	-18,762
2009	0	0	0	0	-1,647,057	-2,846,579	-1,647,057	-2,846,579	-25,194	-43,956
2010	0	0	0	0	-2,003,282	-4,849,862	-2,003,282	-4,849,862	-30,132	-74,088
2011	0	0	0	0	-2,196,997	-7,046,858	-2,196,997	-7,046,858	-32,520	-106,609
2012	0	0	0	0	-2,220,095	-9,266,954	-2,220,095	-9,266,954	-32,265	-138,873
2013	0	0	0	0	-1,830,994	-11,097,948	-1,830,994	-11,097,948	-26,209	-165,082
2014	0	0	0	0	-1,398,306	-12,496,254	-1,398,306	-12,496,254	-19,453	-184,535
2015	0	0	0	0	-958,047	-13,454,301	-958,047	-13,454,301	-12,803	-197,338
2016	0	0	0	0	-710,983	-14,165,284	-710,983	-14,165,284	-9,320	-206,658
2017	0	0	0	0	-482,514	-14,647,797	-482,514	-14,647,797	-6,157	-212,815

3.3 Leakage

VM Step 8: Ex ante estimation of leakage

VM 8.1 Ex ante estimation of the decrease in carbon stocks and increase in GHG emissions due to leakage prevention measures

VM 8.1.1 Carbon stock changes due to activities implemented in leakage management areas

The leakage prevention activities that the project will implement are, to a large extent, defined by each individual community they are meant for. (The activities are mainly implemented through the small grants programme financed from the sale of the VCUs generated by the project (see Section 1.8).) This ensures that the communities are undertaking activities or benefiting from investments that are well suited to their circumstances and needs, and are more likely to succeed. The project does however work with the communities to develop activities that are environmentally sustainable and will not support activities that are not. Consequently the leakage management measures include a suite of improved agriculture and alternative income development, such as:

- Improved water management, and the construction of irrigation systems and small reservoirs;
- Promoting biological anti-erosion measures and the planting of hedges / natural barriers;
- Adopting zero- or low-tillage cultivation techniques;
- Bee keeping;
- Chicken rearing;
- Putting in place agroforestry;
- Reforestation and enrichment planting of degraded natural forest;
- Establishing community or private woodlots for fuelwood, charcoal production and timber;
- Improving the long term sustainability of savoka fallows through the use of native species and better management of the Tavy-savoka cycle.

In addition to agriculture and alternative livelihood activities, the project funds broader community developments, such as wells, repairs to classrooms and construction of granaries. In addition to the small grants programme, the project will implement conservation agreements in the leakage management areas. The agreements are a form of direct payments, typically for activities such as forest patrols or community-based monitoring.

The leakage management activities will not introduce or significantly increase livestock, nor plan to burn or clear significant areas of biomass.

In summary, the leakage prevention measures are likely to lead to a positive net change in carbon stocks; particularly as they include a number of actions, carried out on a broadscale, to increase carbon stocks in cropland through conservation agriculture, as well as to improve the management and supply of forest resources. The net increase is conservatively ignored in the calculation of net GHG emission reductions of the project activity.

The leakage prevention activities are not associated with other VCS or UNFCCC registered project activities. In addition, the consumption of fossil fuels, as a result of the project activity, is considered always insignificant by the methodology and not considered in this project. The estimated net carbon stock change and non-CO₂ emissions in LMAs are thus considered to be zero. A map of the LMAs is provided in Figure 11a and 11b.

VM 8.1.2 Ex ante estimation of CH₄ and N₂O emissions from grazing animals

Although, there is some tradition or current practice of grazing animals in the larger landscape encompassing the project area, it is in a very small scale and insignificant. There is no significant grazing of animals within the leakage management areas nor does the project activity plan to increase the number of grazing animals as a leakage management activity. Therefore we do not estimate the increase in emissions of methane (CH₄) and nitrous oxide (N₂O) from grazing animals in leakage management areas.

VM 8.1.3 Total ex ante estimated carbon stock changes and increases in GHG emissions due to leakage prevention measures

No significant sources are reported.

VM 8.2 Ex-ante estimation of the decrease in carbon stocks and increase in GHG emissions due to activity displacement leakage

We use activity data for classes (Method 1) to estimate the *ex ante* baseline carbon stock changes within the leakage belt, reported in VM Tables 21c.

The *ex-ante* estimation of carbon stock changes and GHG emissions in the leakage belt is based on the assumed effectiveness of the leakage prevention activities. Following the methodology, a Displacement Leakage Factor (DLF) is used as a proxy for this effectiveness and is estimated as a percentage of baseline carbon stock changes within the project area that are displaced within the leakage belt.

The project is implementing leakage prevention measures with all of the communities surrounding the project area. It therefore will include most baseline agents in leakage prevention activities and project activities. Given the scale of the leakage management areas, the prevention measures will take three to five years to become fully operational. We therefore conservatively use a Displacement Leakage Factor (DLF) of 20% for the first 10 years. This is conservative because of the relatively little resources available to the actors; difficulties in relocation; and the project activities and leakage prevention measures carried out with all of the deforestation agents inside and around the project site. Leakage will be monitored as described in the Section 3, and actual deforestation caused project activity shifting will be discounted to the avoided deforestation in the project area

VM Table 34. Ex ante estimated leakage due to activity displacement

Project year	Total ex ante estimated decrease in carbon stocks due to displaced deforestation		Total ex ante estimated increase in GHG emissions due to displaced forest fires	
	annual	cumulative	annual	cumulative
	$\Delta CADLK_t$ tCO ₂ -e	$\Delta CADLK$ tCO ₂ -e	$EADLK_t$ tCO ₂ -e	$EADLK$ tCO ₂ -e
2008	-327,112	-327,112	-3,752	-3,752
2009	-470,198	-797,310	-5,039	-8,791
2010	-604,217	-1,401,527	-6,026	-14,818
2011	-695,189	-2,096,716	-6,504	-21,322

2012	-724,788	-2,821,504	-6,453	-27,775
2013	-783,626	-3,605,130	-5,242	-33,016
2014	-716,273	-4,321,403	-3,891	-36,907
2015	-613,916	-4,935,319	-2,561	-39,468
2016	-603,348	-5,538,667	-1,864	-41,332
2017	-607,967	-6,146,635	-1,231	-42,563

VM 8.3 *Ex ante* estimation of total leakage

The total *ex ante* leakage estimation is reported in VM Table 35.

VM Table 35. Ex ante estimated total leakage

Project year	Total ex ante GHG emissions from increased grazing activities		Total ex ante estimated increase in GHG emissions due to displaced forest fires		Total ex ante estimated decrease in carbon stocks due to displaced deforestation		Net carbon stock changes due to leakage prevention measures		Total net carbon stock change due to leakage		Total net increase in emissions due to leakage	
	annual $EgLK_t$ tCO ₂ -e	cumul $EgLK_t$ tCO ₂ -e	annual $EADLK_t$ tCO ₂ -e	cumulative $EADLK$ tCO ₂ -e	annual $\Delta CADLK_t$ tCO ₂ -e	cumulative $\Delta CADLK$ tCO ₂ -e	annual $\Delta CLPMLK_t$ tCO ₂ -e	cumul. $\Delta CLPMLK$ tCO ₂ -e	annual ΔCLK_t tCO ₂ -e	cumulative ΔCLK tCO ₂ -e	annual ELK_t tCO ₂ -e	cumulative ELK tCO ₂ -e
2008	0	0	-3,752	-3,752	-327,112	-327,112	0	0	-327,112	-327,112	-3,752	-3,752
2009	0	0	-5,039	-8,791	-470,198	-797,310	0	0	-470,198	-797,310	-5,039	-8,791
2010	0	0	-6,026	-14,818	-604,217	-1,401,527	0	0	-604,217	-1,401,527	-6,026	-14,818
2011	0	0	-6,504	-21,322	-695,189	-2,096,716	0	0	-695,189	-2,096,716	-6,504	-21,322
2012	0	0	-6,453	-27,775	-724,788	-2,821,504	0	0	-724,788	-2,821,504	-6,453	-27,775
2013	0	0	-5,242	-33,016	-783,626	-3,605,130	0	0	-783,626	-3,605,130	-5,242	-33,016
2014	0	0	-3,891	-36,907	-716,273	-4,321,403	0	0	-716,273	-4,321,403	-3,891	-36,907
2015	0	0	-2,561	-39,468	-613,916	-4,935,319	0	0	-613,916	-4,935,319	-2,561	-39,468
2016	0	0	-1,864	-41,332	-603,348	-5,538,667	0	0	-603,348	-5,538,667	-1,864	-41,332
2017	0	0	-1,231	-42,563	-607,967	-6,146,635	0	0	-607,967	-6,146,635	-1,231	-42,563

3.4 Summary of GHG Emission Reductions and Removals

VM Step 9: Ex ante net anthropogenic GHG emission reductions

VM 9.1 Significance assessment

The following carbon pools and sources of GHG emissions are considered in this project: above-ground biomass, below-ground biomass, deadwood, and CH₄ from biomass burning. All carbon pools and sources of GHG emissions considered in this methodology were assessed for their significance using the latest approved EB-CDM "Tool for testing significance of GHG emissions in A/R CDM project activities". The results are shown in Table 13.

Table 13. Test of Significance of GHG emissions

Pool/source	included / excluded	expected emissions tCO ₂ /10years	total anthropogenic GHG emissions tCO ₂ /10years	proportion	observations
above ground	included	8,164,210	10,119,729	81%	mandatory
below ground	included	1,190,645	10,119,729	12%	significant
dead wood	included	583,887	10,119,729	6%	significant
litter	excluded	-	10,119,729	-	conservatively excluded
organic soil carbon	excluded	-	10,119,729	-	conservatively excluded
wood products	excluded	-	10,119,729	-	not a significant activity in the area
CH ₄ from forest fires	included	180,986	10,119,729	2%	not significant but included
N ₂ O from animal grazing	excluded	-	10,119,729	-	not a significant activity in the area

VM 9.2 Calculation of ex-ante estimation of total net GHG emissions reductions

The net anthropogenic GHG emission reductions of the CAZ REDD project were calculated using Equation (19) of VM0015:

$$\Delta \text{REDD}_t = (\Delta \text{CBSLP}_t + \text{EBBBSLP}_t) - (\Delta \text{CPSP}_t + \text{EBBPSP}_t) - (\Delta \text{CLK}_t + \text{ELK}_t)$$

Where:

ΔREDD_t Ex ante estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year t ; tCO₂e

ΔCBSLP_t Sum of baseline carbon stock changes in the project area at year t ; tCO₂e

EBBBSLP_t Sum of baseline emissions from biomass burning in the project area at year t ; tCO₂e

ΔCPSPAt tCO_2e	Sum of ex ante estimated actual carbon stock changes in the project area at year t;
EBBPSPAt at year t; tCO_2e	Sum of (ex ante estimated) actual emissions from biomass burning in the project area
ΔCLKt	Sum of ex ante estimated leakage net carbon stock changes at year t; tCO_2e
ELKt	Sum of ex ante estimated leakage emissions at year t; tCO_2e
t 1, 2, 3 ... T,	a year of the proposed project crediting period; dimensionless

Results are reported in VM Table 36.

VM 9.3 Calculation of ex-ante Voluntary Carbon Units (VCUs)

The number of Voluntary Carbon Units (VCUs) to be generated through the CAZ REDD project activities were calculated based on Equations (20; 21) of VM0015 and are summarised in VM Table 36. The Risk Factor (RF_t) applied is 10% based on the Non-Permanence Risk Assessment.

$$\text{VCUt} = \Delta\text{REDDt} - \text{VBCt} \quad (20)$$

$$\text{VBCt} = (\Delta\text{CBSLPAt} - \Delta\text{CPSPAt}) * RF_t \quad (21)$$

Where:

VCUt	Number of Verified Carbon Units that can be traded at time t; $\text{t CO}_2\text{e}$
ΔREDDt	Ex ante estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year t; $\text{tCO}_2\text{e ha}^{-1}$
VBCt	Number of Buffer Credits deposited in the VCS Buffer at time t; $\text{t CO}_2\text{e}$
$\Delta\text{CBSLPAt}$	Sum of baseline carbon stock changes in the project area at year t; tCO_2e
ΔCPSPAt	Sum of ex ante estimated actual carbon stock changes in the project area at year t; $\text{tCO}_2\text{e ha}^{-1}$
RF_t	Risk factor used to calculate VCS buffer credits; %
t 1, 2, 3 ... t,	a year of the proposed project crediting period; dimensionless

VM Table 36. Ex ante estimated net anthropogenic GHG emission reductions ($\Delta REDD_t$) and Voluntary Carbon Units (VCU_t)

Proj year	Baseline carbon stock changes		Baseline GHG emissions		Ex ante project carbon stock changes		Ex ante project GHG emissions		Ex ante leakage carbon stock changes		Ex ante leakage GHG emissions		Ex ante net anthropogenic GHG emission reductions		Ex ante VCUs tradable		Ex ante VCUs buffer	
	annual	cum	annual	cum	annual	cum	annual	cum	annual	cum	an/	cum	annual	cum	annual	cum	annual	cum
	$\Delta CBSLPA_t$	$\Delta CBSLPA$	$EBBB_{SLPA_t}$	$EBBB_{SLPA}$	$\Delta CPSPA_t$	$\Delta CPSPA$	$EBBP_{SPA_t}$	$EBBP_{SPA}$	ΔCLK_t	ΔCLK	ELK_t	ELK	$\Delta REDD_t$	$\Delta REDD$	VCU_t	VCU	VCU_t	$VCUB$
	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e	tCO ₂ -e
2008	-1,635,559	-1,635,559	-25,582	-25,582	-1,199,522	-1,199,522	-18,762	-18,762	-327,112	-327,112	-3,752	-3,752	111,993	111,993	68,389	68,389	43,604	43,604
2009	-2,350,992	-3,986,551	-35,962	-61,544	-1,647,057	-2,846,579	-25,194	-43,956	-470,198	-797,310	-5,039	-8,791	239,465	351,458	169,071	237,461	70,393	113,997
2010	-3,021,084	-7,007,635	-45,441	-106,985	-2,003,282	-4,849,862	-30,132	-74,088	-604,217	-1,401,527	-6,026	-14,818	422,868	774,325	321,087	558,548	101,780	215,777
2011	-3,475,947	-10,483,581	-51,452	-158,437	-2,196,997	-7,046,858	-32,520	-106,609	-695,189	-2,096,716	-6,504	-21,322	596,188	1,370,513	468,293	1,026,841	127,895	343,672
2012	-3,623,939	-14,107,520	-52,667	-211,104	-2,220,095	-9,266,954	-32,265	-138,873	-724,788	-2,821,504	-6,453	-27,775	693,005	2,063,518	552,620	1,579,461	140,384	484,057
2013	-3,918,130	-18,025,649	-56,084	-267,188	-1,830,994	-11,097,948	-26,209	-165,082	-783,626	-3,605,130	-5,242	-33,016	1,328,143	3,391,661	1,119,429	2,698,890	208,714	692,770
2014	-3,581,367	-21,607,016	-49,823	-317,010	-1,398,306	-12,496,254	-19,453	-184,535	-716,273	-4,321,403	-3,891	-36,907	1,493,267	4,884,927	1,274,960	3,973,851	218,306	911,076
2015	-3,069,579	-24,676,595	-41,022	-358,032	-958,047	-13,454,301	-12,803	-197,338	-613,916	-4,935,319	-2,561	-39,468	1,523,275	6,408,202	1,312,121	5,285,972	211,153	1,122,229
2016	-3,016,742	-27,693,337	-39,545	-397,577	-710,983	-14,165,284	-9,320	-206,658	-603,348	-5,538,667	-1,864	-41,332	1,730,772	8,138,974	1,500,196	6,786,168	230,576	1,352,805
2017	-3,039,837	-30,733,174	-38,787	-436,364	-482,514	-14,647,797	-6,157	-212,815	-607,967	-6,146,635	-1,231	-42,563	1,980,755	10,119,729	1,725,022	8,511,191	255,732	1,608,538

4 MONITORING

4.1 Data and Parameters Available at Validation

Data Unit / Parameter:	2005 Forest Cover Benchmark
Data unit:	Map
Description:	Digital map showing the location of forest land within the project area at the beginning of the crediting period
Source of data:	Landsat 5 and Landsat 7 (VM Table 05)
Value applied:	2 ha of forest patch as minimum threshold
Justification of choice of data or description of measurement methods and procedures applied:	Landsat-based land-cover classification using decision tree and see 5 methods The minimum map accuracy is 90% for the classification of forest/non-forest in the remote sensing imagery
Any comment:	Raster format – 30m resolution – projection system UTM zone 38S – datum WGS84

Data Unit / Parameter:	Reference region
Data unit:	Map
Description:	Digital map of reference region boundaries
Source of data:	GIS data (elevation, slope, protected areas, precipitation, forest type...)
Value applied:	Criteria of similarity with project area
Justification of choice of data or description of measurement methods and procedures applied:	The limits were delineated based on landscape configuration, ecological aspects, drivers and agents of deforestation, and social and economic conditions ArcGIS 9.3
Any comment:	Vector format – 30m resolution – projection system

	UTM zone 38S – datum WGS84
--	----------------------------

Data Unit / Parameter:	Leakage Belt
Data unit:	Map
Description:	Digital map of leakage belt boundaries
Source of data:	GIS data (elevation, slope, routes, urban centers, forest edges, project boundaries) and historical deforestation patterns
Value applied:	
Justification of choice of data or description of measurement methods and procedures applied:	Mobility analysis using a multi-criteria evaluation. Factor maps were based on fuzzy analysis using the historical deforestation patterns as parameters Eigenvector of weights applied in the factors maps IDRISI Taiga
Any comment:	Raster format – 30m resolution – projection system UTM zone 38S – datum WGS84

Data Unit / Parameter:	ABSLRR _{i,t}
Data unit:	ha.y ⁻¹
Description:	Annual areas of baseline deforestation in the reference region
Source of data:	Historical deforestation (1990 – 2000 – 2005) (MINENVEFT et al., 2009)
Value applied:	
Justification of choice of data or description of measurement methods and procedures applied:	Annual deforestation was estimated using a national deforestation analysis carried out by the Ministry of Water and Forests and CI (MINENVEFT et al., 2009). It is based on the interpretation of Landsat imagery from 1990, 2000 and 2005.

Any comment:	
--------------	--

Data Unit / Parameter:	Projected Forest Cover Maps (2008-2017)
Data unit:	Map
Description:	Digital maps of yearly forest cover in the project area and leakage belt for 2008-2017
Source of data:	GIS data
Value applied:	
Justification of choice of data or description of measurement methods and procedures applied:	Spatial modeling based on the relationship between historical deforestation and factor maps The minimum map accuracy is 4.4% using figure of merit (FOM)
Any comment:	Raster format – 30m resolution – projection system UTM zone 38S – datum WGS84

Data Unit / Parameter:	AGB
Data unit:	tCO ₂ ha ⁻¹
Description:	Above Ground Biomass carbon pool of trees, derived through application of allometric equation
Source of data:	Field measurements and allometric equation
Value applied:	608.6
Justification of choice of data or description of measurement methods and procedures applied:	Allometric equation derived by Vieilledent et al., 2012 (Mada II.1): $[AGB]_{est} = \exp (-1.159 + 2.297 \log (D) + 0.83 \log (\rho))$
Any comment:	Local and forest type specific equation derived in Madagascar

Data Unit / Parameter:	DBH
Data unit:	cm
Description:	Diameter at Breast Height
Source of data:	Field measurements
Value applied:	Values as measured in the field
Justification of choice of data or description of measurement methods and procedures applied:	SOPs were based on Winrock's methodology (Walker et al., 2008)
Any comment:	n/a

Data Unit / Parameter:	ρ
Data unit:	g/cm ³
Description:	Wood density
Source of data:	Asner et al., 2012
Value applied:	0.61
Justification of choice of data or description of measurement methods and procedures applied:	Default value of regional mean wood density
Any comment:	See supplementary material of Asner et al., 2012

Data Unit / Parameter:	AGB (non-forest class)
Data unit:	tCO ₂ ha ⁻¹
Description:	Above Ground Biomass carbon pool of fallows
Source of data:	Field measurements
Value applied:	42.4
Justification of choice of data or description of measurement methods and procedures applied:	SOPs were based on Winrock's methodology (Walker et al., 2008)

Any comment:	n/a
--------------	-----

Data Unit / Parameter:	BGB (forest class)
Data unit:	tCO ₂ ha ⁻¹
Description:	Below Ground Biomass carbon pool of trees
Source of data:	Derived by AGB
Value applied:	113.3
Justification of choice of data or description of measurement methods and procedures applied:	Default root:shoot ratio for tropical forests derived from Cairns et al., 1997 $\exp(-1.0587 + 0.8836 \times \ln \text{AGB})$
Any comment:	Default Root:shoot ratio also used by IPCC GPG 2003 for tropical forests (Table 4.A.4)

Data Unit / Parameter:	BGB (non-forest class)
Data unit:	tCO ₂ ha ⁻¹
Description:	Below Ground Biomass pool of fallows (savoka)
Source of data:	Derived by AGB
Value applied:	17
Justification of choice of data or description of measurement methods and procedures applied:	Default root:shoot ratio derived from IPCC 2006, Table 4.4, value for tropical shrub land (0.4)
Any comment:	n/a

Data Unit / Parameter:	DW
Data unit:	tCO ₂ ha ⁻¹
Description:	Dead Wood pool
Source of data:	Field measurements

Value applied:	54.4
Justification of choice of data or description of measurement methods and procedures applied:	Equations in Winrock SOPs applied
Any comment:	n/a

Data Unit / Parameter:	CF
Data unit:	dimensionless
Description:	Carbon fraction of dry matter
Source of data:	IPCC GPG LULUCF, 2003
Value applied:	0.5
Justification of choice of data or description of measurement methods and procedures applied:	IPCC default value
Any comment:	n/a

Data Unit / Parameter:	$FBurnt_{icl}$
Data unit:	%
Description:	Proportion of forest area burned during the historical reference period in the forest class <i>icl</i>
Source of data:	Analysis of agents and drivers of deforestation
Value applied:	100
Justification of choice of data or description of measurement methods and procedures applied:	Main driver of deforestation in the reference area is slash and burn agriculture (<i>Tavy</i>)
Any comment:	n/a

Data Unit / Parameter:	$Pburnt_{p,icl}$
Data unit:	%

Description:	Average proportion of mass burnt in the carbon pool p in the forest class icl
Source of data:	IPCC, 2006
Value applied:	32
Justification of choice of data or description of measurement methods and procedures applied:	default IPCC 2006 value for tropical primary forest, Table 2.6
Any comment:	n/a

Data Unit / Parameter:	CEp, icl
Data unit:	dimensionless
Description:	Average combustion efficiency of the carbon pool p in the forest class icl
Source of data:	IPCC GPG LULUCF, 2003
Value applied:	0.5
Justification of choice of data or description of measurement methods and procedures applied:	Default IPCC value
Any comment:	See section: 3.2.1.4.2.2 Choice of Removals/ Emission Factors

4.2 Data and Parameters Monitored

In addition to the data listed below that will be collected directly at every verification period, the applicable tables of VM0015 will be updated with ex-post values, following the same format as in the PD.

Data Unit / Parameter:	Forest Cover Maps
Data unit:	map
Description:	Digital map of forest cover in the project area and leakage belt for verification period
Source of data:	Landsat 5 and Landsat 7
Description of measurement methods and	Landsat-based land-cover classification using decision tree methods. GPS waypoints might be

procedures to be applied:	used during the ground truthing
Frequency of monitoring/recording:	At every verification period
Value applied:	2 ha of forest patch as minimum mapping unit
Monitoring equipment:	ERDAS 10.0 and ArcGIS 10.1
QA/QC procedures to be applied:	Quality Control and Assurance procedures are detailed in the Methodological Annex. The minimum map accuracy is 80% for the classification of forest/non-forest in the remote sensing imagery.
Calculation method:	n/a
Any comment:	Raster format – 30m resolution – projection system UTM zone 38S – datum WGS84

Data Unit / Parameter:	ABSLPA _{i,t}
Data unit:	ha / y ⁻¹
Description:	Annual area of observed deforestation in the project area for verification period per forest strata
Source of data:	GIS processing
Description of measurement methods and procedures to be applied:	Results of overlaying the forest cover map with the project area boundaries
Frequency of monitoring/recording:	At every verification period
Value applied:	GIS files of the project boundary
Monitoring equipment:	Computer and ArcGIS 10.1
QA/QC procedures to be applied:	Projection system and datum will be kept consistent. Clear and detailed documentation and independent desk review to assure consistency and accuracy of the GIS procedures
Calculation method:	Spatial Analysis tool (tabulate area of zonal statistics tool box)

Any comment:	n/a
--------------	-----

Data Unit / Parameter:	ABSLLKi,t
Data unit:	ha / y ⁻¹
Description:	Annual area of observed deforestation in the leakage belt for verification period per forest strata
Source of data:	GIS processing
Description of measurement methods and procedures to be applied:	Results of overlaying the forest cover map with the leakage belt boundaries
Frequency of monitoring/recording:	At every verification period
Value applied:	GIS file of the leakage belt
Monitoring equipment:	Computer and ArcGIS software
QA/QC procedures to be applied:	Projection system and datum will be kept consistent. Clear and detailed documentation and independent desk review to assure consistency and accuracy of the GIS procedures
Calculation method:	Spatial Analysis tool (tabulate area of zonal statistics tool box)
Any comment:	n/a

4.3 Description of the Monitoring Plan

For a technical description of the CAZ monitoring plan, please refer to VM Tasks 1 and 2 below. The data and parameters monitored during the project's lifetime are described in the previous section of this PD. Below follows a description of the data management plan of the project⁶.

Purpose of the CAZ GHG monitoring plan:

- Standardize methods and procedures applied for the collection, compilation and analyses of the data used to estimate the GHG benefits of the CAZ project;

⁶ The CAZ data management plan was designed based on the data management and publishing guidelines of the MIT Libraries, available at: <http://libraries.mit.edu/guides/subjects/data-management/index.html>

- Guarantee that the information is processed in a consistent way throughout the project's lifetime, comparable with the data and processes used during validation and in accordance with VCS approved methodology VM0015;
- Assure that the GHG benefits are estimated in a conservative manner with accuracy, precision and reliability;
- Document results to demonstrate the achievement of the CAZ project's goals in terms of emissions reductions.

Organization(s) and staff involved:

The responsible organization for the data management will be Conservation International, supported by the CAZ partners as appropriate:

- Overall administration and supervision: Project Director - CI Madagascar
- Data storage and organization: GIS technician CAZ - CI Madagascar
- Back up and system security: IT manager - CI-Madagascar
- Remote sensing processing: RS specialist - CI-Madagascar//HQ
- GIS analysis - GIS technician CAZ: CI-Madagascar
- Documentation and outreach: Communications coordinator - CI-Madagascar

Description of the data to be collected:

- The GHG benefits of the CAZ project will be estimated by comparing the baseline emissions with the actual emissions during each monitoring period. The actual emissions will be estimated by measuring the forest loss multiplied by the emission factor. Note that the emission factors will be constant during the project lifetime, since the carbon stock of the forest class is considered constant. Therefore the only data to be measured in each monitoring event will be forest loss due to land use change.
- Forest loss will be estimated in each monitoring period by analyzing a time series of Landsat images. Subsequently, the forest loss map will be overlaid with the project area and leakage belt to estimate the area converted to non-forest within those boundaries.
- Images will be compiled from USGS and UMD archives, with enough dates within one year period to ensure the least amount of cloud problems possible. In the cases where areas obscured by clouds still remain in the project area and leakage belt, these areas will be temporarily excluded from the project monitoring until the next verification period.

Plans for storage and data management:

- All the GIS data, including the raw and processed satellite images will be stored in the GIS lab of CI-Madagascar.

- All data will initially be backed up using an external drive with weekly backups to a network drive. The network drive uses CI's SAN server system and provides redundant backup. This will ensure that a retrieval system will be in place in case of computer, hardware, or internet connection failure.
- The folder structure will be reflected in the backup system to guarantee that the integrity of GIS map files (i.e.. mxd for ArcGIS) will be maintained and links will not be broken.
- The backup system will be tested systematically (monthly) to ensure that the system is working properly.
- Any data collected in hard copy (paper) will be converted to digital (i.e. scanners), unless otherwise specified in the monitoring report. In that case, a physical location in the GIS-lab of CI-Madagascar will be designated to store such material. An electronic inventory document will identify the name, type of document and a brief description of all the hard copy products. This inventory will be located in the GIS-lab of CI-Madagascar.
- The GIS manager of CI-Madagascar will be responsible for keeping any hard copies in a secure location, protected from intense humidity or sunlight exposure. In addition, the GIS Manager will be in charge of collecting, copying and storing any relevant files generated by the CAZ partners or external consultants.
- All documents and records will be kept in a secure and retrievable manner (described above) for at least two years after the end of the project crediting period.

Plans for data transfer:

- In case Conservation International ceases to be the Implementing Partner or ceases to be in charge of the carbon monitoring aspects of the project, all data will be transferred to the Project Proponent and/or the entity indicated by the Project Proponent that will continue this task. Conservation International would transfer the entire external hard drive, where all the GIS and non-GIS related to this project is stored to the appointed manager. By doing that, all the folder structure will remain the same and the links created by GIS software will be preserved. Any map document or project database will be complete and could easily be accessed. Conservation International will also ensure to train and inform the new responsible regarding database and information management, updates and back-up system.

Legal and ethical issues:

- The data collected or generated by the CAZ project are property of CI-Madagascar unless otherwise specified. Confidentiality of research subjects, where applicable, will be maintained to ensure continuing participation in research and monitoring activities.

Access policies and provisions:

- All data collected or generated by the CAZ project will be publicly available upon request through the contact information provided in the PD, unless under contractual obligation not to be disclosed.

VM Task 1: Monitoring of carbon stock changes and GHG emissions for periodical verifications

VM 1.1 Monitoring of actual carbon stock changes and GHG emissions within the project area

VM 1.1.1 *Monitoring of project implementation*

Annual Project implementation plans are developed at the start of each year describing the activities to be conducted. These are updated and revised as needed on a periodic basis and more detailed monthly activity plans are developed from them. Monthly monitoring of project activities and tracking of progress against the monthly plans occurs through a monthly meeting of the project team. Annual reports are used to assess progress against the annual objectives as defined in annual plans.

Field missions, field agent reports, meeting minutes and reports on specific activities are stored in the main CI office for CAZ at Toamasina. Copies are kept with the staff responsible for the activities and with the Regional coordinator. Copies of any reports produced by service providers or grantees are also stored on CI's internet-based Data management system (GEM – Grants Enterprise Management). Specific reports on major activities such as the community small grants program, conservation agreements, protected area creation are also stored on CI's intranet and *eroom* systems.

VM 1.1.2 *Monitoring of land-use and land-cover change*

As of the date of validation no regional, national or jurisdictional monitoring system of land-use and land-cover change was in place. Therefore, the project proponent will be responsible for developing the land-use and land-cover change component of the monitoring plan for the project area and leakage belt. The analysis will cover the monitoring of forest land converted to non-forest. Accuracy assessment as described in steps 2.4 and 2.5 of part 2 will be performed. The minimum accepted accuracy of the final classification will be 80%.

The project proponent will complete the following technical steps:

1. Acquire appropriate Landsat images with minimal cloud cover
2. Atmospherically correct images
3. Orthorectify images to within one pixel using a single base image (generally a GeoCover image, or similar image, used to generate the forest benchmark map)
4. In areas where no-data values exist in the base image (due to clouds, cloud shadows, SLC-off artefacts), composited images will be generated using the base image and multiple gap-filling images. A cloud, cloud shadow, and SLC-off mask for the base image will first be generated and gap-filling scenes identified to fill the mask of the base image. Temporal and gap extent criteria will be used to select the gap-filling scenes; scenes with similar acquisition dates will be given preference, as well as minimal cloud, cloud shadow, and SLC-off gap artefacts.

5. Classify images in two-date image stacks using decision tree analysis (a combination of ERDAS and See5, or similar). Only areas which were forested in the baseline period will be classified, as they are the only class subject to deforestation.
 - a. Map classes include: 1=forest, 2=non-forest, 4=water, and 5=cloud
 - b. Collect training data to represent both change and non-change areas
 - c. Include numerous sub-classes in the training data for each land-cover and change class, to incorporate the full range of spectral variability within the image
6. Filter classifications using a three step process:
 - a. Neighbourhood majority filter 3x3, corners unchecked
 - b. Clump, 4 way
 - c. 2-hectare eliminate
7. To produce multi-date classifications the new classification will be merged with the existing classification. In the updated map product each digit in the final classification represents the land-cover at the corresponding time period.

To ensure a high quality analysis, the project proponent will closely follow the methods, rules and procedures specified in Conservation International's standard change detection methodology (provided as supplementary information).

The project proponent will continue to use, primarily, Landsat images, as this source is expected to keep providing continued coverage, at low or no-cost, due to the Landsat Data Continuity Mission (LDCM). However, in the cases where Landsat imagery is not available or cannot provide adequate coverage, other types of imagery will be used. When incorporating other types of imagery it is important to consider spectral resolution, spatial resolution, continuity, seasonality, and context. Context refers to the types of activity in the area, such as in an area that is not likely to experience deforestation due to a lack of accessibility. Regardless of the data used, all the images will be co-registered to the baseline image.

Imagery with acquisition dates as close as possible to the reporting period date will be used. The forest benchmark map and source imagery used for the historical analysis will also be consulted to ensure maximum consistency in image interpretation. This will include using the image-display stretches used during the historical analysis, in order to minimize the risk of inconsistent interpretation. All data used to create the updated map and the resulting classification will be stored and backed-up along other GIS data.

The final product will be validated with high resolution imagery (i.e. 5 meter spatial resolution or less) and/or field-collected ground-truth data. The minimum accuracy for each land-cover class will be 80%. In addition, accuracy assessments of the decision tree generation will be conducted using a stratified sampling method with 50% of the training done to test how well the model fits the training data. Analyst interpretation will still be necessary to determine the best land-cover product and adjust the model using multiple iterations.

VM 1.1.3 *Monitoring of carbon stocks and non-CO₂ emissions*

Since no harvesting activities above the baseline are planned and existing harvesting activities do not significantly change carbon stocks, the project will not monitor carbon stock decreases except in the case of catastrophic events. The project does not seek to be credited for any carbon stock increases.

Monitoring of carbon stocks	VM requirement	Project monitoring	Explanation
Within the project area:			
Areas subject to significant carbon stock decrease in the project scenario according to the <i>ex ante</i> assessment. These will be areas subject to controlled deforestation and planned harvest activities, such as logging, fuel wood collection and charcoal production. In these areas, carbon stock changes must be estimated at least once after each harvest event	Mandatory	No	As the project area is comprised of strict conservation areas (with no harvesting) and sustainable use areas (where residents can continue baseline sustainable harvesting of forest resources according to agreed upon quotas) the project activity does not entail planned harvest activities above the baseline.
Areas subject to unplanned and significant carbon stock decrease, e.g. due to uncontrolled forest fires and other catastrophic events. In these areas, carbon stock losses must be estimated as soon as possible after the catastrophic event. See section 1.1.4 below for more detailed guidance	Mandatory	Yes	
Areas subject to carbon stock increase after planned harvest activities, such as logging, fuel wood collection and charcoal production. In these areas, the carbon stock increase occurring after the harvest event can be measured and accounted, when significant.	Optional	No	The project proponent does not seek to be credited for these carbon stock increases
Areas recovering after disturbances, such unplanned forest fires and other catastrophic events. In these areas, the carbon stock increase occurring after the catastrophic event can be	Optional	Yes	The project will also monitor the recovery of these areas after disturbances. If there is a significant carbon stock increase it will be accounted.

measured and accounted, when significant. See section 1.1.4 below for more detailed guidance.			
Within leakage management areas:			
Areas subject to planned and significant carbon stock decrease in the project scenario according to the ex ante assessment. In these areas, carbon stocks must be estimated at least once after the planned event that caused the carbon stock decrease.	Mandatory	No	Carbon stocks with the leakage management areas are not subject to planned and significant decreases in the project scenario and will not be monitored.
Areas subject to carbon stock increase due to leakage prevention measures. In these areas, the carbon stock increase can be measured and accounted only up to the amount necessary to offset any carbon stock decrease caused by leakage prevention measures in other leakage management areas or in previous years.	Optional	No	The project proponent does not seek to be credited for these carbon stock increases
Within the leakage belt:			
Areas undergoing significant changes in carbon stock may be measured at the end of each fixed baseline period in order to update carbon stock information for the subsequent period.	Optional	No	

Monitoring of non-CO2 emissions from forest fires

The main driver of deforestation in the project area is *Tavy*, which includes burning. The project thus seeks crediting for reducing baseline non-CO₂ emissions from forest fires. The variables of VM Table 23 within the project area will be monitored and reported in VM Table 24.

VM 1.1.4 Monitoring of impacts of natural disturbances and other catastrophic events

Natural disasters that might affect the carbon stocks (i.e. hurricanes, volcanic eruptions, flooding, severe droughts, earthquakes) in CAZ are uncommon and do not represent a significant risk for the project area as assessed in the Non-Permanence Risk Report. However, the project proponent will use medium-

resolution satellite images to monitor catastrophic events, applying the methodology described in Task 1, Section 1.1.2 and through field visits for ground-truthing.

The project will consider a second tier of monitoring that comprises the rapid monitoring of deforestation hotspot areas. This will be based on readily available near real-time decision support tools. Two such tools, developed by Conservation International, are the Fire Alert System (FAS) and the Illegal Logging and Encroachment Monitoring System. FAS uses MODIS active fire data to generate daily email alerts of active fire locations. This system can be customized by the user, such as the project manager, to track and respond to fire and associated deforestation activity captured in specific areas of interest. The Illegal Logging and Encroachment Monitoring System uses visual interpretation of high resolution imagery – such as Landsat, ASTER, and ALOS AVNIR– to quickly generate alerts highlighting areas of forest encroachment and illegal logging, whenever cloud-free data become available within target areas of interest.

VM 1.1.5 Total ex post estimated actual net carbon stock changes and GHG emissions in the project area

Relevant tables will be updated using the new measurements of changes in carbon stocks and GHG emissions in each monitoring period. The results will be summarized in the VM Table 29: Total ex-post estimated actual net changes in carbon stocks and emissions of GHG in the project area.

VM 1.2 Monitoring of leakage

VM 1.2.1 Monitoring of carbon stock changes and GHG emissions associated to leakage prevention activities

No planned deforestation or degradation is expected to occur as part of leakage prevention activities, and no changes in carbon stocks are expected to occur according to the ex-ante analysis.

VM 1.2.2 Monitoring of carbon stock decrease and increases in GHG emissions due to activity displacement leakage

Deforestation in the leakage belt will be monitored using CI's standard change detection methodology (provided to the validators as supplementary information). Any deforestation above the baseline in the leakage belt will be discounted from the carbon emissions avoided due to project activities. If emissions in the leakage belt are higher than the baseline due to activities not attributed to the project, the project proponent will collect robust evidence to justify that the deforestation is not linked to project activities.

Emissions from forest fires are included in the baseline therefore increases in GHG emissions will also be monitored in the leakage belt.

VM 1.2.3 Total ex post estimated leakage

The results of all ex-post estimations of leakage through monitoring will be summarized using the same table format used in the ex-ante assessment and will be reported in VM Table 35: Total ex-post estimated leakage.

VM 1.3 Ex post net anthropogenic GHG emission reductions

The calculation of ex-post net anthropogenic emission reductions will be estimated similarly to the ex-ante calculation using the equation below:

$$\Delta REDD_t = (\Delta CBSLPA_t) - (\Delta CPSPA_t) - (\Delta CLK_t + ELK_t)$$

Where:

$\Delta REDD_t$	Ex-post estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year t ; tCO ₂ e
$\Delta CBSLPA_t$	Sum of baseline carbon stock changes in the project area at year t ; tCO ₂ e
$\Delta CPSPA_t$	Sum of ex post estimated actual carbon stock changes in the project area at year t ; tCO ₂ e
ΔCLK_t	Sum of ex post estimated leakage net carbon stock changes at year t ; tCO ₂ e
ELK_t	Sum of ex post estimated leakage emissions at year t ; tCO ₂ e
t	1, 2, 3 ... T , a year of the proposed crediting period; dimensionless

The results of all ex-post net anthropogenic GHG emission reductions will be summarized using the same table format used in the ex-ante assessment and will be reported in VM Table 36: Ex-post net anthropogenic GHG emission reductions and VCU. In addition a map showing the Cumulative Areas Credited will be produced and updated at each monitoring event.

VM Task 2: Revisiting the baseline projections for future fixed baseline period

The baseline proposed for CAZ will be revised in 2017. If by this date no regional, national or jurisdictional baseline has been developed, the project proponent will revisit and update the baseline.

VM 2.1 Update information on agents, drivers and underlying causes of deforestation

Information on drivers and agents of deforestation in the reference region will be collected periodically. Prior to 2017, a workshop will be organized with local representatives, experts and stakeholders to validate the information collected and discuss strategies to mitigate the drivers of deforestation. The approach used in this public consultation will be based on the *Open Standards for the Practice of Conservation*. The results of this workshop will be also used to identify the variables to be used in the deforestation modeling.

VM 2.2 Adjustment of the land-use and land-cover change component of the baseline

VM 2.2.1 Adjustment of the annual areas of baseline deforestation

As more information becomes available on land-use and land-cover change and the causes of deforestation, the annual rates of deforestation will be re-estimated. If conclusive information on historical deforestation is available to project deforestation rates for the next baseline period, appropriated approach (i.e. "a" average "b" time function or "c" modeling) will be used. The methods used will follow

steps 3 and 4 of part 02 of the VCS VM0015 methodology. If an applicable sub-national or national baseline becomes available during the fixed baseline period, it will be used for the subsequent period.

VM 2.2.2 Adjustment of the location of the projected baseline deforestation

Using the adjusted annual deforestation rate, the location will be spatially distributed using the Land Change Modeler (LCM) tool in IDRISI, or other similar spatially explicit modeling software. Any improved spatial and/or tabular data will be reassessed and used in the modeling. New factor maps and a risk map will be produced for the project and leakage belt, and the accuracy of the modelling will be assessed using the equation described in section 4.2 of this document. The leakage belt will be revised and its boundary delineated based on a mobility analysis, unless the agents and drivers of deforestation have changed substantially and another method for defining the boundary of the leakage is more suitable.

VM 2.3 Adjustment of the carbon component of the baseline

The project will use the carbon stock measurements for the entire project crediting period, unless more accurate data is available and covering all the carbon pools considered by the project.

5 ENVIRONMENTAL IMPACT

No negative environmental impacts are identified in the Environmental and Social Impact assessment. The project consists of protecting natural forest and biodiversity, does not involve building any infrastructure and is therefore overwhelming positive in terms of its environmental impact. The following text summarizes the section on environmental impacts in the Environmental and Social Impact assessment that has been developed in compliance with the MECIE Decree and will be submitted to the National Environment Office for approval in 2012:

The creation and management of the Ankeniheny-Zahamena Protected area, as Natural Resource Reserve (equivalent to an IUCN category VI protected area), with its emphasis on sustainable use of natural resources, aims to protect ecosystem services and to contribute to the development and to the well-being of the local human population. This large protected area, classified as one of the priority areas for conservation in Madagascar, contains the majority of the remaining rainforest in the central eastern part of the country. In addition to rainforest, the area includes important river systems. These habitats are home to many species, including Madagascar endemics and endangered species of lemurs, birds, amphibians, reptiles, fish and plants. New discoveries in the corridor occur regularly and further research is likely to also uncover new species. However, the practice of slash and burn activities, leading to deforestation and illegal logging and small scale mining, which degrade the forest, are threats to the forest ecosystem. To achieve the management objectives of the protected area, a participatory approach was used to design strategies that have been included in the Management Plan of the Protected Area, which is the main framework document for activities that need to be undertaken in this protected area. These activities are all designed to maintain the ecological balance and ecosystem functions through sustainable use of resources. Strategies defined as "key" for the establishment and effective management of the protected area are: (1) public and local and regional authorities integration in the corridor management system of Ankeniheny-Zahamena for a better protection of resources (2) integration of the protected area in the regional, local and national main document references (3) the improvement of the living standards of local populations (4) development and implementation of sustainable financing

mechanisms. Indeed, the resulting activities aim at protecting the habitats and species of the area and the intrinsic values of the protected area, while ensuring that they will not harm the welfare of neighboring communities. Monitoring and evaluation of project activities on a regular basis will help to make a readjustment of these management strategies for the sustainability of the protected area.

6 STAKEHOLDER COMMENTS

Stakeholder consultations and outcomes

The creation of a protected area in Madagascar requires detailed stakeholder consultation at each key step. The project has fulfilled these requirements in compliance with the national laws and the World Bank safeguard Operational Procedures 4.12. Formal consultations with national and local stakeholders began in 2004 with the initiative to create the protected area and have been ongoing since.

In particular, Malagasy law requires significant community consultation and participation in establishing the boundaries of new protected areas. Local communities, local and regional authorities (traditional and administrative), representatives of the relevant government departments were all consulted in this process. From 2005 to 2007, meetings were held in every village within the communes concerned by the protected area limits to discuss, negotiate and validate the limits. During the protected area delimitation, a formal process existed for all community members to voice their complaints. The minutes of each village meeting and their formal agreement to the protected area limits are available to the validator on request. The limits were further agreed on at regional and national levels with the relevant stakeholders.

Inclusive consultations also took place during the definition of the protected area governance structure and management plan, the social impact assessment and the establishment of compensation payments and alternative livelihoods for forest stakeholders. Reports on these processes are provided in the supporting documents. The main outcomes were:

- a co-management that includes members of the local communities, regional and national government authorities and CI;
- a protected area management plan that takes into account the needs of local stakeholders;
- the communities that will be impacted by the protected area were identified;
- what the initial compensation must be paid to stakeholders;
- and what the alternative livelihoods are that they want to develop.

Public consultations in defining boundaries of the protected areas, land use planning, losses for households during protected area creation and safeguards/compensation measures for losses, are conducted in a participatory way, as a negotiation. Each session is documented by a meeting minute, integrating comments, recommendations of the targeted group. All these minutes validated locally and signed are gathered in a folder, as an annex of the Environmental and Social Safeguard Management Plan. All these documents are available.

On-going communication

The co-management structure of the protected area, together with the transfer of the management of its buffer zone to the resident communities, forms an inclusive mechanism for ongoing stakeholder communication.

7 ANNEXES

Annex 1: References

- Andriambolantsoa R., Ramaroson B., Randriamanantsoa P., Ranaivosoa R., Razafindramanga M., Harper, G. and Steininger M. (2007) Madagascar : Change in natural forest cover 1990-2000-2005. Digital map produced by CI, IRG, ONE, FTM, ESSA-FORETS. In Evolution de la couverture des forets naturelles 1990 – 2000 – 2005 Madagascar, MINENEVEF, Antananarivo, Madagascar and USAID, Washington, DC, USA.
- ANGAP (2001) Madagascar Protected Area System Management Plan. ANGAP, Antananarivo. 112pp.
- Asner G. P., Clark J. K., Mascaro J., Vaudry R., Chadwick K. D., Vieilledent G., Rasamoelina M., Balaji A., Kennedy-Bowdoin T., Maatoug L., Colgan M. S. and Knapp D. E. (2012). Human and environmental controls over aboveground carbon storage in Madagascar. Carbon Balance and Management. 7:2.
- Aubert S., Razafiarison S., Bertrand, A. (2003). Deforestation et systemes agaires à Madagascar. Les dynamiques des Tavy sur la côte orientale. CIRAD
- Birkinshaw, C., Randrianjanahary, M. (2007). "The Effects of Cyclone Hudah on the Forest of Masoala Peninsula, Madagascar." Madagascar Conservation & Development, Volume 2 (1), p.17-20.
- Brand, J., Pfund, J.L., (1998) Site and watershed-level assessment of nutrient dynamics under shifting cultivation in eastern Madagascar. Agric. Ecosyst. Environ. 71, 169–183.
- Busson, F., Andriamiarinosy, M., Monteils, F., Randrianarison, M. (2009). REDD à Madagascar: état des lieux et expériences en cours. Green Synergy, Unpublished report to the Madagascar REDD Technical Committee. 110 p.
- Carret, J-C., Loyer, D. (2003). « Comment financer durablement les aires protégées à Madagascar? Apport de l'analyse économique » Banque mondiale/Agence Française de Développement. Presentation, World Parks Congress/Durban.
- Cairns, M.A., Brown, S., Helmer, E.H., Baumgardner, G.A. (1997). Root biomass allocation in the world's upland forests. Oecologia, 111(1), 1-11.
- Clark Laboratories (2008). Land Change Modeller software package.
<http://www.clarklabs.org/products/Land-Change-Modeler-Overview.cfm>
- Dufils, J. -M., (2003) Remaining forest cover. In: Goodman, S.M., Benstead, J.P. (Eds.), The Natural History of Madagascar. The University of Chicago Press, pp. 88–96.
- Dynatec, (2006). Environmental Assessment Ambatovy Project. Madagascar. Available at <http://www.documbase.com/Madagascar-Ambatovy-Project.pdf>
- Elmqvist, T., M. Pyykõnen, et al. (2007). "Patterns of Loss and Regeneration of Tropical Dry Forest in Madagascar: The Social Institutional Context." PLoS ONE 2(5): e402. doi:10.1371/journal.pone.0000402 May 2007(5): 1 - 14.
- Ferguson, H.B. (2009). "REDD in Madagascar: An Overview of Progress", Independent Report, 20 August 2009, and references cited therein.

FAO (2009). Rapport spécial - Mission FAO/PAM d'évaluation de la sécurité alimentaire à Madagascar, août 2009

Fondation pour les Aires Protégées et la Biodiversité de Madagascar (2010) Rapport Annuel.

Ganzhorn, J. U., Langrand, O., Wright, P. C., O'Connor, S., Rakotosamimanana, B., Feistner, A. T. C. and Rumpler, Y. (1997). "The state of lemur conservation in Madagascar." *Primate Conservation* 17: 70-86.

Global Witness and Environmental Investigation Agency (2010) Investigation into the global trade in Malagasy Precious Woods: Rosewood, Ebony and Palisander. EIA and Global Witness, 31pp.

Gorenflo L.J., Catherine Corson, Kenneth M. Chomitz, Grady Harper, Miroslav Honzak and Berk Ozler (2011) *In* R.P. Cincotta and L.J. Gorenflo (eds.), Human Population: Its Influences on Biological Diversity, Ecological Studies 214. Springer-Verlag Berlin Heidelberg

Government of Madagascar, (2006). Madagascar Action Plan, Commitment Six – High Growth Economy, Madagascar. Available at <http://www.un.org/esa/coordination/Alliance/MADAGASCAR%20ACTION%20PLAN.htm>

Green G and Sussman R.W. (1990) Deforestation history of the Eastern Rainforests of Madagascar from Satellite images. *Science* 248:212-215. Harper, G.J., Steininger, M.K., Tucker, C.J., Juhn, D., Hawkins, F. (2007) Fifty years of deforestation and forest fragmentation in Madagascar. *Environmental Conservation* 34:1-9.

Harper, G. J., M. K. Steininger, C.J. Tucker, D. Juhn and F. Hawkins, (2007). Fifty years of deforestation and forest fragmentation in Madagascar. *Environmental Conservation* 34(4):325-533

Hawkins, F. & Horning, N. (2001). Forest cover change in USAID and control areas. A preliminary evaluation and report to USAID and partners. PAGE, Antananarivo. July 2001. pp 21.

INSTAT - Institut National de la Statistique. (2010) Enquete Demographique et de Santé de Madagascar 2008-2009. Madagascar. Available at <http://www.instat.mg/pdf/eds2008-2009.pdf>

IPCC (Intergovernmental Panel on Climate Change). (2003). Good Practice Guidance on Land Use, Land Use Change and Forestry. IPCC, Geneva, Switzerland. Available at <http://www.ipcc-nggip.iges.or.jp>

IPCC (Intergovernmental Panel on Climate Change). (2006). Draft 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry, and Other Land Use. Available at <http://www.ipcc-nggip.iges.or.jp>

Jarjala (2005) Support sustainable environment and forest ecosystems management in Madagascar. Report on an Action Plan to Improve Governance in the Forestry Sector.

Jarjala (2007) Analyse de la Couverture forestiere de Madagascar entre 2000-2005. Rapport d'Atelier.

Jarjala (2009) Evolution de la couverture des forêts naturelles à Madagascar 1990-2000-2005. Ministère de l'Environnement, des Forests et du Tourisme, USAID, Conservation International.

Kauffman, J.B., Till, K.M., Shea, R.W. (1992). Biogeochemistry of deforestation and biomass burning. In: Dunnette, D.A., O'Brien, R.J. (Eds.), *The Science of Global Change*. American Chemical Society, Washington, DC.

Keck, A. (2001). "The National Conservation Finance Planning Process in Madagascar". *Projet d'Appui à la Gestion de l'Environnement*. Prepared for USAID/Madagascar, 13 p.

Kistler, P., and S. Spack (2003) Comparing agricultural systems in two areas of Madagascar. Pages 123–134 in S. M. Goodman and J. P. Benstead, editors. *The natural history of Madagascar*. University of Chicago Press, Chicago.

MacKinnon J., Holmes C., Reed E., Randrianarisoa J., Rabesahala H., Abdallah A. C. , Rabesahala V. and Victorine R, (2009). *Sustainable financing of Madagascar's Protected Area System: Progress and Future Priorities*. USAID

P. Mayaux, V. Gond & E. Bartholome (2000): A near-real time forest-cover map of Madagascar derived from SPOT-4 VEGETATION data, *International Journal of Remote Sensing*, 21:16, 3139-3144

Mansourian, S., Dudley, N. (2008). "Public Funds to Protected Areas" WWF International, 43 p.

Martin Emily A., Lalaina Ratsimisetra, Francis Laloe, Stephanie M. Carriere (2009). "Conservation value for birds of traditionally managed isolated trees in an agricultural landscape of Madagascar", *Biodiversity Conservation*, DOI 10.1007/s10531-009-9671-x

Messerli P., (2004). Alternatives à la culture sur brûlis sur la falaise est de Madagascar: Strategies en vue d'une gestion plus durable des terres. *Geographica Bernensia* A17. 348pp.

MEF - Ministère de l'Environnement et des Forêts, (2010). *Quatrième Rapport National de la Convention sur la Diversité Biologique*. MEF, Antananarivo. 148pp.

MINENVEFT - Ministère de l'Environnement des Forêts et du Tourisme / USAID - United States Agency for International Development and Conservation International / CI – Conservation International (2009) « Evolution de la couverture de forêts naturelles à Madagascar 1990-2000-2005 », 132 p.

MINENVEF - Ministère de l'Environnement des Forêts et du Tourisme & CI -Conservation International (2012) *Plan de Gestion Environnementale et de Sauvegarde Sociale de la Réserve de Ressources Naturelles Ankeniheny-Zahamena*, MINENVEF, 135pp

Minten B., Randrianarisoa Jean-Claude, Randrianarison L. (2003). *Agriculture, pauvreté rurale et politiques économiques à Madagascar*. Cornell, 107pp.

Moat J and Smith P. (2007) *Atlas of the Vegetation of Madagascar*. Kew Publishing, Royal Botanic Gardens, 124pp.

Montagne P., Razafimahatratra S, Rasamindisa A, Crehay R. (2010). *Arina: Le Charbon de Bois à Madagascar, entre demande urbaine et gestion durable*. CITE, Antananarivo. 187pp.

Moser C., (2008): An economic analysis of deforestation in Madagascar in the 1990s, *Environmental Sciences*, 5:2, 91-108

ONE (2008) « *Tableau de bord environnemental national* », 411 p.

- Pardieu, V. and N. Rakotosoana, (2012). Ruby and Sapphire Rush near Didi, Madagascar. GIA Laboratory, Bangkok Thailand. Available at <http://www.gia.edu/research-resources/news-from-research/index.html>
- Pearson, T., Walker, S.M., Brown, S. (2006). Sourcebook for Land use, Land use change, and Forestry Projects. BioCarbon Fund, World Bank.
- Raik, D. (2007). "Forest Management in Madagascar: An Historical Overview." *Madagascar Conservation & Development* 2(1): 5 – 10
- Razafimpahanana, A. et al. (2008). « Priorisation : une approche pour l'identification des zones importantes pour la conservation à Madagascar », 14 p.
- Ratsifandrihamanana, A. N., D. Montanye, et al. (2006). "Socioeconomic Root Causes of Biodiversity Loss in Madagascar." *USDA Forest Service Proceedings RMRS-P-42CD*: 203 - 212.
- R-PP (2010) Proposition des mesures pour l'état de préparation, Madagascar, Aout 2010, Fonds de partenariat pour le carbone forestier (FCPF), 107 p.
- Serpantie G., Rasolofoharinoro, Carrière S. (2007). Transitions agraires, dynamiques écologiques et conservation. CIRAD, Antananarivo.
- Styger, E., Rakotondramasy, H.M., Pfeffer, M.J, Fernandes, E.C.M, and Bates, D.M. (2007). Influence of slash-and-burn farming practices on fallow succession and land degradation in the rainforest region of Madagascar. *Agriculture, Ecosystems and Environment* **119**: 257-269
- Styger, E., Fernandes, E.C.M, Rakotondramasy, H.M., and Rajaobelirina, E. (2009). Degrading uplands in the rainforest region of Madagascar: Fallow biomass, nutrient stocks, and soil nutrient availability. *Agroforestry Systems*, April 17 online
- UNFCCC (2008). Minimum values for national forest definition, Madagascar. Located at: <http://cdm.unfccc.int/DNA/ARDNA.html?CID=1>. Retrieved 11/15/08
- USAID - United States Agency for International Development (2005) Support sustainable environment and forest ecosystem management in Madagascar. Report on an Action Plan to improve governance in the forestry sector. IRG, 63pp.
- USAID - United States Agency for International Development (2010) Paradise Lost? Lessons from 25 years of USAID Environment Programs in Madagascar. USAID.
- Vieilledent G., Vaudry R., Andriamanohisoa S. F. D., Rakotonarivo O. S., Randrianasolo H. Z., Razafindrabe H. N., Bidaud Rakotoarivony C., Ebeling J. and Rasamoelina M. (2012). A universal approach to estimate biomass and carbon stock in tropical forests using generic allometric models. *Ecological Applications*. 22(2): 572-583.

Wemaere M. & Rajonson G. (2006) « Note sur la nature juridique du carbone et les droits de propriété sur les crédits carbone » 14 p.

World Bank, (2005); Madagascar Public Expenditure Review: The Challenge of Poverty Reduction, World Bank, Washington DC, US. 187 p.

World Bank (2010) Madagascar: Vers un agenda de relance économique. World Bank, Antananarivo. 364pp.

World Bank (2011) Supporting urgent biodiversity conservation in Madagascar. News and Views. Available at <http://www.worldbank.org/en/news/2011/06/23/supporting-urgent-biodiversity-conservation-in-madagascar>

World Bank (2012). World Development Indicators 2012. World Bank, Washington DC. Available at <http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2012>

Annex 2: List of relevant Malagasy legislation

Code de gestion des aires protégées 2008 « Loi n° 2008-025 du 25 Novembre 2008 portant refonte du code de gestion des aires protégées »

Charte de l'environnement et ses modificatifs (Loi n° 90-033 du 21 décembre 1990 modifiée par les lois n° 97-012 du 06 juin 1997 et n° 2004-015 du 19 août 2004)

Loi n° 96-025 du 30 septembre 1996 relative à la gestion locale des ressources naturelles renouvelables

Loi n° 97-017 du 8 août 1997 portant révision de la législation forestière

Loi 2006-031 fixant le régime juridique de la propriété foncière privée non titrée

Loi 2008-014 sur le domaine privé de l'Etat, des Collectivités Décentralisées et des personnes morales de Droit public.

Loi 2004-001 relative aux Régions

Décret n° 99-954 du 15 décembre 1999 (MECIE) relatif à la mise en compatibilité des investissements avec l'environnement

Décret n° 2004 – 167 (MECIE) modifiant certaines dispositions du décret n° 99-954 du 15 décembre 1999 relatif à la mise en compatibilité des investissements avec l'environnement

Décret n° 98-610 du 13 août 1998 réglementant les modalités de la mise en oeuvre de la Sécurisation Foncière Relative

Décret n° 2000-027 du 13 janvier 2000 relatif aux communautés de base chargées de la gestion locale des ressources naturelles renouvelables

Décret n° 2000-028 du 14 février 2000 relatif aux médiateurs environnementaux

Arrêté interministériel n° 4355 / 97 Portant définition des zones sensibles

Arrêté interministériel n° 19560/2004 Portant suspension de l'octroi de permis minier et permis forestier dans les zones réservées comme « sites de conservation »

Arrêté interministériel n° 17914/2006 du 18 Octobre 2006 prorogeant la suspension de l'octroi de permis minier et permis forestier dans les zones classés en réserve qui sont les « sites de conservation et les sites de gestion forestière durable »

Arrêté interministériel n° 18633/2008 portant mise en protection temporaire globale des sites visés par l'Arrêté interministériel n° 17914/2006 du 18 Octobre 2006 et levant la suspension de l'octroi de permis minier et permis forestier pour certains sites.

Annex 3: CAZ REDD Project Parcel ID Boundaries

Parcel ID	Coordinates of centroid		Area (ha)	Land tenure
	Lat	Long		
1	48.44175328640	-19.09083857480	36043.64	State land
2	48.68266983820	-18.23730945320	330689.46	State land
3	48.87809193050	-17.77255670450	348.05	State land
4	48.96967760010	-18.17824390190	4166.81	State land
5	48.98195065310	-18.40703396730	815.97	State land
6	48.96321567270	-18.49835920510	2162.86	State land
7	48.89949837110	-18.51784865340	194.39	State land
8	48.89545507930	-18.55148949300	286.98	State land
9	48.87674050820	-18.42482846690	702.42	State land
10	48.71466080210	-18.55015888250	1121.07	State land
11	48.76758033620	-18.67396889190	2826.88	State land